Artillery 2000

Ian V. Hogg

For some while after the awesome events of 6 August 1945, artillery assumed a secondary role in the new age of nuclear weaponry. Design and production resources were switched to intercontinental ballistic firepower and the high altitude bomber. Few fresh conventional artillery developments took place.

Now, in a cycle of events that is rare in technical evolution, artillery has made a comeback, albeit with equipment and projectiles dramatically advanced from those deployed in the Second World War. Today, the creative teams in the international defence industry have been switched from the overcrowded missile technology to apply their basic principles to the soldier's friend – artillery.

The result is a revolution – still in progress – that has seen automatic loading systems, auxiliary propulsion, laser sighting and now 'smart' ammunition, longer guns with greater power, and promises of more innovation to come. By the turn of the century even more dramatic changes in artillery will have taken place.

This timely publication will enable the reader to be more alive to the nuances of military technology and applied science as the perceived advances take place. The author uses his knowledge, built from a lifetime of observation, research and practical experience, to offer an informed prediction of the type of artillery that will be in use at the start of the 21st century.

KINGS BAY GA.

A

An 8in (203mm) M110 howitzer in Vietnam in 1969.

tillery 2000

Ian V. Hogg

ARMS AND
ARMOUR

First published in Great Britain in 1990 by Arms and Armour Press, Villiers House, 41/47 Strand, London WC2N 5JE.

Distributed in the USA by Sterling Publishing Co. Inc., 387 Park Avenue South, New York, NY 10016-8810.

Distributed in Australia by Capricorn Link (Australia) Pty. Ltd., P.O. Box 665, Lane Cove, New South Wales 2066.

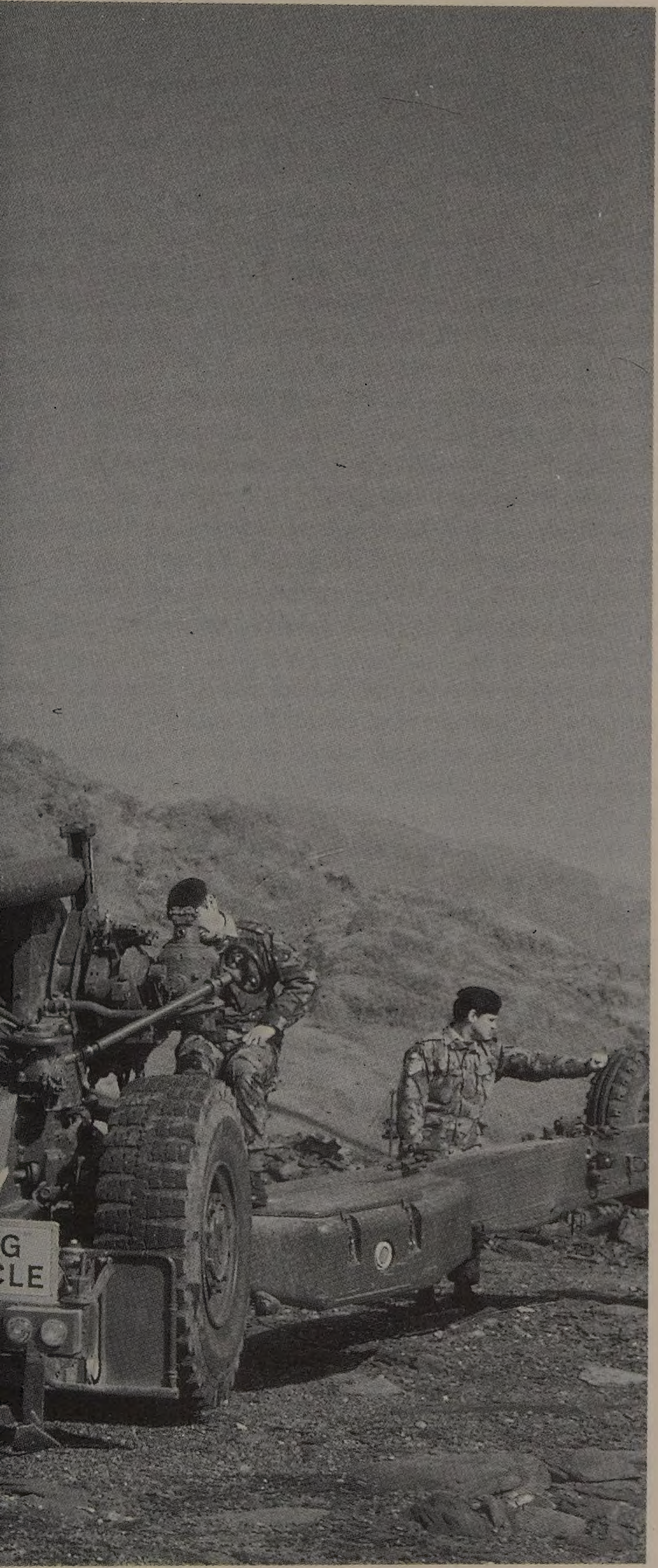
British Library Cataloguing in Publication Data
Hogg, Ian V. (Ian Vernon), *1926–*
Artillery 2000.
1. Artillery
I. Title
623.41
ISBN 0-85368-983-0

Jacket illustrations: Front, the Bofors FH-77 155mm howitzer (see page 47); back, the Spanish 155/39 REMA howitzer (see page 54; picture courtesy of Santa Barbara).

Designed and edited by DAG Publications Ltd. Designed by David Gibbons; edited by Michael Boxall; layout by Anthony A. Evans; typeset by Typesetters (Birmingham) Ltd., Warley; camerawork by M&E Reproductions, North Fambridge, Essex; printed and bound in Great Britain by The Bath Press, Avon.

▶
The 155mm FH-70 howitzer in firing position. (Vickers Shipbuilding & Engineering)

CONTENTS



The purpose of artillery is to support the infantry and armour elements of the army in attack and defence. Although artillery bombardment can, sometimes, bring about the total collapse and surrender of an enemy force, artillery is not considered as a decisive weapon in its own right, and its supporting role is one that is well understood and of which it is justifiably proud. You cannot win battles by artillery alone; but equally so, you are unlikely to win battles without artillery.

At 8 a.m. on 6 August 1945, artillery was *ultima ratio regum* – the last argument of kings – as it has been for centuries. By 8.30 a.m. it had been relegated to a secondary role; the nuclear bomb had usurped it as the ultimate weapon. Suddenly the planners and theorists found they had an immense power of bombardment placed in their hands which made conventional artillery no more potent than firecrackers. All the resources of nations were thrown into the development of missiles and aircraft which could deliver this terrible weapon anywhere on earth, and from this research came not only the nuclear intercontinental ballistic missile and the stratospheric bomber but all manner of smaller missiles, not necessarily with nuclear warheads, which would, it was prophesied, take over the entire artillery function and render the gun obsolete. By way of a sop to the traditionalists, tactical nuclear artillery was devised, and the few conventional artillery weapons that were developed during the period 1945–60 were more inclined towards protection from nuclear attack than towards their tactical effectiveness as artillery pieces.

But eventually all this furious endeavour has defeated itself and as the turn of the century approaches it seems that artillery is well on the way to regaining its former (and rightful) place in battle. The strategic bomber can no more be guaranteed to hit its target than it could forty years ago, and the chances of it actually reaching its target are jeopardized by the power of air defence missiles. The ballistic missile has reached such levels of power and ingenuity that it has sterilized itself, insofar as no sensible nation would dare use one for fear of the retaliation sure to come. Moreover, in spite of impressive tests and glowing commendations from manufacturers, there is no guarantee that such missiles will, in the event of being used in earnest, perform as immaculately as promised; what a weapon does in the rarified atmosphere of a test range and what it does in the rather more down-to-earth hands of soldiers in active service conditions are not necessarily related.

And so the planners and soldiers have at last put false gods behind them and turned back to what is (sometimes in a disparaging tone) called 'conventional warfare'. And that means artillery.

It surprised many people that, in the final stages of the brief Falklands campaign in 1982, with every possible modern and scientific weapon deployed and with air power of the most up-to-date type available on call, it was actually the bombardment of Port Stanley by two regiments of field artillery that brought about the collapse of Argentinian resistance and the surrender of their forces. This is well-attested fact, and not myth. Artillery fire is frequently called an 'area weapon' when the fact is that modern guns can be used with surgical precision, as they were at Port Stanley, to bring fire to bear upon carefully selected and discrete targets in a manner that can persuade an enemy that he is virtually under a microscope and that his every move invites shellfire.

The Falklands campaign was also of value in that it revealed the power of artillery to the rest of the army. The British Army had not conducted any operation supported by artillery since the Borneo Confrontation in 1963, and indeed the artillery support there was minimal. Periodic peacetime demonstrations of 'firepower', attended by soldiers from infantry and armour, could merely suggest the effect of gunfire, since the ammunition available for demonstration purposes allowed only token bombardments against featureless areas on gunnery ranges. I spent the immediate post-war years as a gun detachment commander in the School of Artillery's demonstration regiment, and fired innumerable demonstrations at a time when ammunition was freely available, a time when a battery in training would fire more ammunition in a day than its 1980s successor sees in a year. And even so, I was powerfully impressed when, a few years later, I first saw a target in Korea swamped by the fire of a division's guns using proximity-fuzed shell; there was simply no comparison between demonstration and active service.

It would be wrong to say that the Falklands affair caused a resurgence of artillery, since an overhaul of that arm had been in progress for some years by that time, but it did have positive effects in reinforcing some theories, demolishing others, reaffirming the worth of gunfire and reminding even the gunners

INTRODUCTION

themselves of what artillery was capable, something which is easily lost sight of during a long spell of unemployment.

Given, therefore, that the soldiers themselves have turned to conventional warfare with enthusiasm, the other side of the coin has been the sudden appeal of artillery to the defence industry. In the past the manufacture of artillery was a highly specialized business conducted by a handful of firms throughout the world. In the 1930s and afterwards much of this business crept away from these experts and fell into the hands of government design bureaux and factories, particularly under the pressure of war, but after 1945 many of these government establishments were closed down and such small amounts of artillery that were made came, once more, from the commercial gun-makers, though often influenced by government designs. Even so, gun manufacture remained within a small group of companies and, with a few exceptions, still does. What has changed radically has been the development of ancillary equipment; in the past the design and production of such things as ammunition and fire control equipment was almost entirely due to official designs produced either in government factories or by outside firms on limited contracts. Rarely was an outside company invited to tender for the design of such equipment, the few cases being confined to highly specialized instruments such an anti-aircraft predictors or radars, and even these were guided by detailed specifications laid down by the users.

In the 1970s, however, the other elements of the defence industry – the manufacturers of electronic devices, the makers of missiles and similar new high-technology firms – found that the rush to the missile age was abating and that they had expensive design staffs sitting on their hands. It behoved them to look elsewhere for ways to apply their particular line in technology, and after reviewing the various things that armies used, they decided that artillery could do with a boost from technology. After all, the basic principles upon which guns and their ammunition were being built had changed little since the 19th century, and it seemed probable that fresh brains, unencumbered with years of traditional thinking, might well see different ways of solving some of the artillery problems.

And they did. In short order the soldiers were being offered guns with auxiliary propulsion, guns with automated loading systems, sophisticated devices for survey and position location, for target acquisition, for calculating basic fire control information. Then came 'smart' ammunition, longer guns of greater power, and promises of even more innovation to come.

We are still in the course of this technological artillery transformation, much of which is promised to reach fruition in the course of the final decade of this century, so that in the year 2000, we are assured on all sides, artillery will have been revolutionized. And what we are about to do in the following pages is to examine the current range of artillery equipment, look at what the innovators and designers have to offer, consider what the function of artillery is, and then reach our own conclusions about what might be seen in the magic year 2000.

ARTILLERY

The artillery weapons in service with the armies of the world in 1989 are a mixture of old and new, tried and untried. With few exceptions they are elderly, conventional and effective. Some have been gradually refined and added to across several years of service, others represent fairly new technology and have had no combat service to prove or disprove their effectiveness. And, without doubt, quite a number of them are going to be around still in the year 2000.

In general, the tendency over the past thirty years has been to do away with the small calibres – below 105mm – and place far more reliance upon the medium calibre of 155mm or its near approximation. This tends to echo a remark made by Field Marshal Lord Alanbrooke in the 1920s when reviewing the artillery developments of the 1914–18 war; 'In peace the cry is for mobility, in war for weight of shell,' though in this case the cry has not waited for war. In peacetime exercises there is always a tendency to place great weight upon mobility and manoeuvre, since these are the only outward and visible signs of efficiency in artillery; as was pointed out in the introduction, the ability of artillery to drop great weights of shellfire on target is frequently lost sight of between wars, and not until the shooting starts is it rediscovered, whereupon the demand is for more and more heavy guns to cause more and more destruction. Modern tactics ask for heavy shell weights in order to obtain the greatest possible return for every shot, since shoot-and-scoot techniques restrict the number of shots that can be fired, so that demand for weight of shell has come about for rather different reasons. The 155mm calibre offers the best compromise between mobility – expressed as weight and bulk of the gun – and shellpower.

In the past armies have fielded guns of calibres up to 80cm, though it has to be admitted that anything above 30cm has been unusual and generally a mere technical trick with little or no tactical value. The largest gun placed in service since 1945 has been the US 28cm 'Atomic Annie' and while this gave everything desired in weight and effect of shell, it was a tiresome beast to move about the countryside, even with American automotive technology utilized to its utmost in a very ingenious design. The problem of moving and concealing this weapon eventually led to its retirement, and ever since then, whenever large calibres have been mooted, the 28cm has been flourished as the bad example to be avoided.

As a result, 203mm (8 inches) is now generally considered to be the maximum calibre for a field weapon, and so far as NATO is concerned the only reason for its retention appears to be its particular suitability for firing a nuclear projectile. Should an improved and sufficiently powerful 155cm nuclear projectile be accepted, there is every chance that the 203mm will go the way of the 28cm; there is no comparable concealment problem, but the 203mm howitzer simply lacks (to the modern thinking) sufficient range to justify its retention except as a nuclear delivery system. There are, though, signs that an improvement in this calibre may be on the way.

Similarly the small calibres which were once so popular as divisional support weapons – 75mm, 77mm 88mm – are now considered to be lacking in both range and shell weight and no longer worth the bother of keeping by Western armies, particularly since those armies have been slimmed down. Differing from this view is, as usual, the Soviet Army, which has so many men that it can afford to squander them on light artillery on the off-chance that there may be something for them to do in war. And, given their manpower, they are undoubtedly right; to those at the target, the number and frequency of the falling shells is more important than their weight, and the rapid hammering of large numbers of 76mm shells can be more devastating to the morale than the more destructive effect of a smaller number of heavy-calibre projectiles.

The world's artillery equipment can be split into some convenient groups. Fully half of it can trace its descent from Soviet drawing-boards. Of the remainder, there is first the enormous group that stems from the US 155mm howitzer M1; a similarly large group which came from the American 105mm howitzer M2A1; then the smaller and most modern group which owes its existence, directly or indirectly, to the Space Research Corporation of Canada. The remainder are the renegades who owe allegiance to nobody – the British 105mm family, the US 175mm and 203mm weapons, the Bofors, OTO-Melara, Santa Barbara and GIAT designs. Anything outside these families is a rarity and generally an elderly rarity at that. What ought to be borne in mind, though, is that most of these families came into being because of the ammunition that the ancestor fired and propagated. There is nothing like a cheap and liberal supply of ammunition to persuade an army that a particular weapon is worth having, and certainly the ease of availability of the US 155mm M107 family of projectiles had a great deal to do with

the rapid assimilation of the 155mm howitzer family throughout the world. Similarly it was the promise of cheap ammunition which brought about the embracement of Soviet calibres by many small nations who attained independence and then needed armament, though they subsequently discovered that the resupply of ammunition depended more upon their political beliefs than upon their ability to pay, and that if their politics strayed too far the supply of ammunition simply dried up. which has made it profitable for a few Western ammunition makers to go into production with Soviet calibres.

By way of reinforcing this argument, the drying up of an ammunition source can frequently result in the abandonment of an odd calibre. The British Army retained the US 240mm howitzer and 8in gun into the 1960s and might well have kept them longer, but for the fact that the Americans ran out of the stockpile of ammunition they had manufactured in the 1940s and saw no point in manufacturing any more.

Another point of view is that if the ammunition is inefficient, and if there is no prospect of improving it, an otherwise perfectly serviceable weapon will be axed. The British adopted the 5.5in gun in 1940, and the projectile, designed in war for manufacture in war, used low-grade steel with the result that it held a relatively low quantity of explosive. This was standard for the time, but as improved ammunition appeared in the 1960s, the defects of the 5.5in shell became more and more apparent, until in the late 1970s the gun was finally made obsolete. Suggestions that the ammunition might be improved were considered but turned down since even an improved 5.5in (134mm) was unlikely to be as effective as the new 155mm projectiles which had been developed for the FH70. And yet the same gun is still in use in South Africa, very successfully, because there they have adapted the most modern ammunition design technology to developing an entirely new projectile, which has resulted in a phenomenal range increase and a new lease of life for the weapon. To the South Africans it made economic and tactical sense; to the British it did not.

In the descriptive section which follows, we will examine the various 'families' outlined above, beginning with the Western nations, and then look at those weapons that are outside the family groups. Because of the manner in which these families of weapons have been distributed, this system of examination avoids much repetition and fragmenting of information.

The US 105mm Howitzer

The American Army began designing a 105mm howitzer as their divisional support weapon as far back as 1919, but between-wars financial stringency meant that the weapon was not standardized until 1936 and did not go into production until 1940, the intervening years having been spent in refining and perfecting the design. The resulting 105mm Howitzer M2A1 became the standard US field-piece of the Second World War; many thousands were produced and in post-war years large numbers were distributed to other countries to equip their post-war armies, particularly European countries that had lost all their equipment to the Germans in 1940–4. The howitzer retained its position in the US Army and in later years was redesigned slightly, to take advantage of modern materials and manufacturing methods, becoming the M101. It was also produced in three different types of self-propelled mounting, and some are still in use by smaller nations.

The principal drawback to the M1/M101 is the ammunition. Designed in the 1930s, the standard HE shell is fired by a seven-part propelling charge contained in a metal case, and attains a maximum range of 11,270 metres. There are also white phosphorus and hexachlorethane smoke shells and a range of chemical projectiles, the latter having been designed but not in production or standard issue. In the 1940s and 1950s the howitzer was also provided with a shaped-charge anti-tank shell, and some of these may still be found with smaller armies, having been abandoned by the US Army in favour of a squash-head projectile.

Eleven thousand metres is by no means a good performance by modern standards, and various experiments have taken place at different times to try and obtain more range. At present the solution is the rocket-assisted HE/RA shell M548 which gives a maximum range of 14,600 metres, though with a reduction in explosive payload and a loss of accuracy.

Other nations, though, have taken the M1/M101 and given it a thorough shaking, finishing with a weapon more to their liking. The German Army discarded the original barrel and replaced it with a longer barrel fitted with a muzzle brake, resulting in a maximum range with the standard shell of 14,100 metres. The French followed a similar course, fitting their own 30-calibre barrel and using a shell of their own design to obtain 15,000 metres' range, though having done so they then lost interest and abandoned the idea.

The only improvement the Americans chose to make to the 105mm howitzer was in the direction of reducing the weight to make it more amenable to helicopter-lifting. Development of this idea began in 1960 and the M102 howitzer was first issued in 1965, being extensively used in Vietnam. The design is considerably different from that of the M2/M101 weapon, using a splayed box trail and a vertical sliding block breech, and the entire equipment weighs only 1,496kg instead of the 2,258kg of the M101. But there is no ballistic improvement over the M2/M101.

The US 155mm Howitzer

US allegiance to the 155mm howitzer goes back to 1917 when they purchased numbers from the French Army with which to arm the AEF, and then put the design into production in the USA. During the 1930s they drew up designs for a more powerful version which was standardized as the 155mm howitzer M1 in April 1941. The M1 was a split-trail equipment using a screw breech mechanism, the barrel carried in a ring cradle with a split recoil mechanism above and below

◄ The American 105mm M1 howitzer is still in wide use; here it is being fired by a Belgian Para-Commando artillery battery, part of the ACE Mobile Force.

► The replacement for the 105mm M1 is the M102, here seen in use by a US Army detachment during NATO exercises in Portugal.

the tube. The breech mechanism was something of an anachronism, being of the 'slow coned' pattern in which the initial movement of the operating lever rotates the screw to the unlocked position; further movement withdraws the screw axially for an inch or so to pull the obturating pad clear of the chamber, and then the remaining movement of the lever swings the breech open. This type of breech was generally abandoned at about the turn of the century for the 'steep coned' type in which the angle of the obturator pad and chamber face allows the breech screw to begin the swing-open motion as soon as it is unlocked; why the Americans chose to adopt the slow cone is something nobody has ever satisfactorily explained. What is more puzzling is that the principle has been perpetuated in subsequent models developed from this design.

Some 6,000 or more M1 howitzers were made before production stopped in the late 1940s, and, as with the 105mm M2A1, hundreds were distributed around the world to refurbish war-depleted armies. The howitzer fired a 43kg shell to a maximum range of 14,955 metres, using a rather complicated charge system which offered seven charges or 'zones'. In post-war years there was a slight redesign and the new weapon became the howitzer M114 but with no ballistic changes. The projectiles developed for this weapon, the Shell HE M107, Smoke WP M110 and Smoke HC M116, were produced in vast quantities and eventually became the NATO standard pattern to which almost every 155mm howitzer built since then has been matched, irrespective of what other ammunition they may be intended to fire.

Like most artillery equipment the M1/M114 is soundly built and likely to last for years; unfortunately it is now ballistically outclassed, and this has led to various attempts to improve matters by discarding the ordnance and grafting a new barrel on to the mounting.

The M114/39 howitzer developed by Voest-Alpine of Austria (now Böhler) has been produced by inserting a new 39-calibre barrel in place of the original 24-calibre

▲ The RDM 114/39 howitzer, a Dutch improvement on the 155mm M114 by fitting a new 39-calibre barrel to the standard carriage. Note that the longer barrel needs to be drawn back to the recoiled position and clamped to the trail for stability during travelling.

pattern. This barrel has an enlarged chamber and is fitted with the semi-automatic screw breech of the GH-N-45 howitzer. In order to balance the additional length, the spring equilibrators are replaced by hydro-pneumatic ones and the firing platform is relocated to the new centre of gravity. The barrel is fitted with a muzzle brake and the recoil mechanism is re-calibrated to withstand the additional force.

In this new form the M114/39 can fire the old standard M107 projectile to a maximum range of 18,500 metres; an alternative barrel, with increasing twist rifling instead of the normal uniform twist, allows a higher charge to be used and increases this range to 21,000 metres. A specially designed low-drag projectile SEN-155-BT has a maximum range with the uniform twist barrel of 24,400 metres, and the SEN-155-BB base-bleed projectile increases this to 30,400 metres. It is not known whether any army has adopted this weapon.

A similar conversion has been made in South Korea, producing the KH-179 howitzer. This, too, is a 39-calibre barrel with muzzle brake fitted into the M114 carriage; the recoil system has been converted and pneumatic equilibrators fitted. The gun is designed to fire NATO standard projectiles, and with a conventional shell achieves a maximum range of 22,000 metres. Using US rocket-assisted shell this can be increased to 30,000 metres. The KH179 is in service with the South Korean Army.

The third conversion, and what appear to be the most successful, are the RDM 155mm M139 and M114/39 howitzers, RDM being a Netherlands engineering company. These two designations are both the same thing, except that the M139 is a newly built gun while the M114/39 is a conversion kit which any purchaser can apply to his existing M114 howitzers. As with the other designs, the principal change is the insertion of a new 39-calibre barrel with muzzle brake and enlarged chamber. This, of course, leads to modification of the firing jack, cradle, recoil system, equilibrators, and elevating gear to cater for the higher loadings. The resulting weapon fires the M107 shell to 18,100 metres, an ERFB shell to 24,600 metres and an ERFBB shell to 30,400 metres.

This weapon (either the kit or the new howitzer) has been supplied to, among others, the Royal Canadian Artillery and the Netherlands Army, and this has led to some interest from other forces.

The US Self-Propelled 155mm Howitzers

A project to put the 155mm howitzer on a self-propelled mounting was begun in mid-1943, using the chassis of the M5 light tank as the basis. At the same time another design study was begun, using the chassis of the proposed M24 light tank, and in early 1944 this latter proposal was chosen to be implemented. Strangely, there appears to have been some resistance to the idea from elements of the US Army, but this was not unusual in those days, when the last people to be consulted about artillery weapons were the artillerymen. Eventually the equipment was standardized as the Howitzer Motor Carriage M41 in May 1945, and although procurement of 500 was authorized, no more than a hundred or so were ever built. It was a fairly spartan equipment, simply the top carriage and barrel of the M1 howitzer planted into a cutaway tank hull, but it proved to be a useful and efficient piece of equipment in Korea.

Meanwhile, in late 1947, it had been decided to develop a light and highly mobile 155mm SP equipment to provide close support for moving columns, and a fresh design was begun. As happens so often the designers went clean over the top and came up with a turreted vehicle carrying a howitzer with muzzle brake and fume extractor, one of the earliest, if not *the* earliest, applications of such a device. There was also to be some highly technical fire control equipment, but before this was finalized there was a complete change of design so as to permit standardization of components with other vehicles in the design stage. Once the new design was settled, some time in late 1950, it was ordered into production forthwith, without waiting for pilots or prototypes. Once the first models had been tested it soon became apparent that the fire control system was a disaster, but some 250 were built before production could be stopped and the design changed. The offending system was removed and replaced by a conventional panoramic sight and clinometer system, production recommenced, and about 600 were built.

The Howitzer Motor Carriage M44, standardized in November 1953, was a tracked, open-hulled vehicle carrying a standard 155mm howitzer M1 on a pedestal carriage. The rear of the hull opened as double doors with ammunition racks inside, and a bulldozer-blade-type spade was lowered by gravity at the rear to stabilize the carriage in action and relieve the suspension of the firing shock. The mounting had powered traverse and elevation and there was also a spring-actuated flick rammer. The driver sat up alongside but higher than the gun, where he had excellent command, and there was a ring-mounted .50 machine-gun behind him.

The M44 was a good equipment, but was soon out of step with the current fashion because it has an open-topped hull, which could be covered with a canvas tilt to keep the gun and crew dry in wet weather, but which offered no protection against nuclear flash and fall-out, and that, by the late 1950s, was a Bad Thing. Nevertheless, the British Army adopted it in 1956 as an interim measure; NATO had agreed that 155mm was to be the 'general support' calibre, and since 155mm had never been a British calibre this meant something had to be bought while something better was designed, and the M44 was chosen.

The M44 had only one serious defect, and that was the firing lock, an over-complicated device which fired either electric or percussion primers. Its design was poor and its execution worse, being made from soft metal which rapidly wore to the point where the firing-pin sear failed to hold. Eventually someone got hurt and the offending lock was removed and replaced with the British 'Lock, Percussion, K' of 1917 vintage, which worked perfectly and this minor change of accessory led to the renaming of the M44, in British service, to become the Howitzer, 155mm L8A1.

Even before the M44 had been put into production, yet another committee sat in Washington and proposed yet another improved 155mm SP howitzer. Proposals were put forward and rejected until in 1956 a design was finally agreed. Prototypes were built, tested, altered, and eventually in 1963 the new design was standardized as the Howitzer, Medium, Self-propelled, M109. This very rapidly replaced the M44 in US service, though a number of M44s are still in use in such countries as Greece, Japan, Spain and Turkey.

The M109 was a vast improvement on the M44 so far as the mechanical side went, though its ballistics were no better than the M1 towed howitzer, with a maximum range of 14,600 metres with the M107 shell. The

▶ The first 155mm M44 howitzer to arrive in British service. The hull was open-topped and the driver's position is indicated by the windscreen to the left of the gun.

chassis was designed for its role, and not a made-over tank chassis; the gun was mounted in a turret at the rear of the hull, capable of traversing through the full 360°. The barrel was fitted with a large muzzle brake and a fume extractor of rather unusual appearance close to the muzzle. The breech mechanism used the same slow cone obturator as the M1, but was arranged for semi-automatic opening on run-out. Elevation and traverse were by hydraulic power.

The M109 was issued to US units very rapidly and was soon being supplied to other nations including all the NATO armies, Jordan, Pakistan, Saudi Arabia, Switzerland, Taiwan, Tunisia and others. However, there were complains about the relatively poor range, and in 1970 the M109A1 was standardized. This has a longer, 39-calibre, barrel with the same muzzle brake but a more slender fume extractor mounted farther back from the muzzle. The remainder of the equipment is much the same, some detail improvements having been made here and there, but the important point is that the range with the M107 shell was increased to 18,100 metres.

In 1979 the M109A2 was put into service. This was essentially the M109A1 with a redesigned rammer, improved recoil mechanism, improved hydraulic system, and a turret bustle which held 22 rounds of ammunition and could be resupplied from outside the vehicle.

By the late 1970s some improved ammunition had been developed which increased the range of all the M109 family. A rocket-assisted projectile, for example, improved the M109A1/2 performance to a maximum range of 24,000 metres and various carrier munitions loaded with mines and bomblets were placed on limited issue.

Some of the recipients of the original M109, though, had not waited for the Americans to carry out improvements but had developed their own ideas. West Germany, for example, threw away the screw breech and replaced it with a sliding block breech developed by Rheinmetall; the adoption of an improved charge system pushed the range up to 18,500 metres, and the equipment became known as the M109G in order to distinguish it. This was followed, in the mid-1980s, by a completely new barrel, also developed by Rheinmetall, which extended the range with conventional projectiles to 24,000 metres and with base-bleed shells to 31,000 metres. This became the M109A3G, though by that time the only thing left of the M109 was the chassis.

Italy purchased M109 chassis without armament from the USA and made their own barrels, to the standard M109 design, in the OTO-Melara factory. In 1970–71 OTO-Melara, as a private venture, developed an entirely new barrel based upon that of the tripartite FH-70 howitzer and fitted this into an M109 chassis.

One of the first 155mm M109 howitzers, clean and shiny from the factory. The oddly shaped fume extractor is evident in this view.


LIFT
HERE

Using FH-70 ammunition this reached to 24,000 metres quite comfortably, but at that stage the Italian Army was not particularly interested, being more concerned with getting their towed FH-70 weapons into service. In the early 1980s, though, the Ministry of Defence ordered three of these conversions to be made and tested, after which the entire stock of Italian M109s were similarly rebuilt. The internal contours of this gun ware such that it can fire the standard M107 family of projectiles, the FH-70 projectile range, and a proposed entirely new family which includes a rocket-assisted shell ranging to over 30 kilometres.

Perhaps the strangest modification of the M109 is that performed in Taiwan, where the turret and its armament is removed and discarded and the top carriage of the M114 towed howitzer mounted in the open rear compartment of the hull. The gun barrel has the muzzle brake of the M109 fitted, but there appears to be no improvement in performance over the original M114. The purpose behind this radical rebuilding has not been formally stated, but it seems probable that weight-saving was a major consideration.

Not satisfied with that, a more recent conversion has been to do away with some of the M114 howitzers and fit a new 45-calibre weapon of unknown origin; it is fitted with a muzzle brake and fune extractor (somewhat superfluous on an open mounting) and according to some sources is derived either from the South African G5 or from the SRC GC-45 design, though other observers have commented upon its similarity to the Israeli Soltam M71. It is reputed to have a range of 30 kilometres with Extended Range Full Bore (ERFB) projectiles and over 35 kilometres with ERFB Base Bleed (ERFB-BB) projectiles.

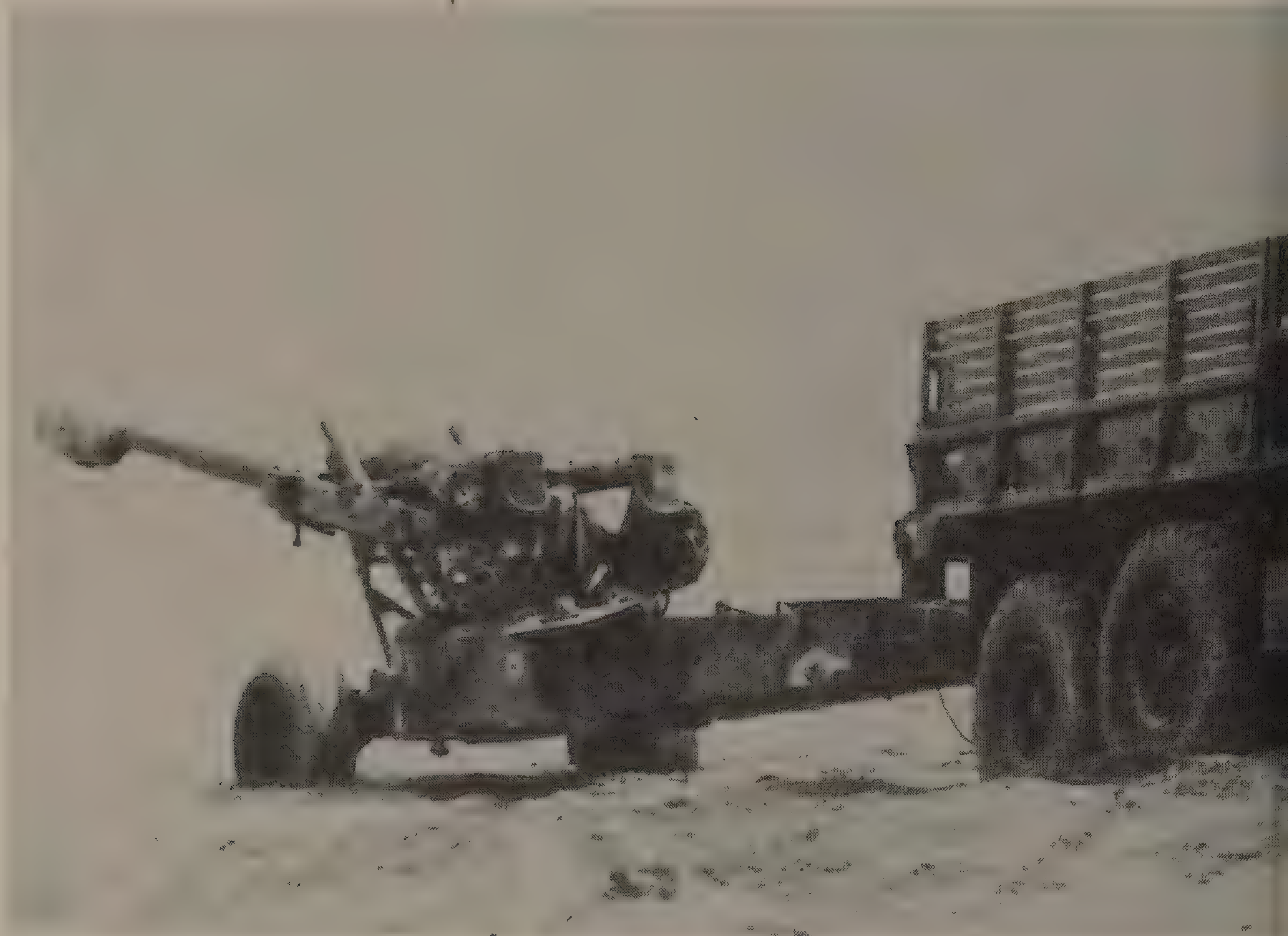
The US 155mm Gun

The US Army adopted the 155mm gun in 1917 when they bought a number of French Mle 1917 'GPF' guns to arm the AEF. During the years that followed more were built in the USA and the M1917 was to remain in service until the Second World War. In the 1920s work began on designing an improved model which was to share the carriage design with an 8-inch howitzer. A number of designs was tried and in 1938 the M1 gun was standardized.

The M1 equipment was an excellent design. The gun was 45 calibres long, with an Asbury screw breech and

◄ The later M109A1, here seen in British service. The longer barrel and new fume extractor can be seen, and the rear turret doors, for ammunition re-supply, are open.

▶
The M198 towed 155mm howitzer, which duplicates the performance of the M114 but does it on an air-portable carriage.



▶
39 Heavy Regiment Royal Artillery firing a 175mm M107 gun in Germany. Note the haze of dust thrown up by firing.

a simple but reliable percussion firing mechanism. It fired a bag charge to propel its 43kg shell to a maximum range of 24,135 metres. The carriage had a four-wheeled bogie and split trail, the ends of which were carried on a two-wheeled limber attached to the towing vehicle. To emplace the weapon, the carriage was lowered and the wheels raised by two screw-jacks, the trails opened and spades fitted. The gun was trunnioned close to the breech, balanced by hydro-pneumatic cylinders, and could reach a maximum elevation of 63°, giving it a considerable tactical flexibility in range.

Two self-propelled 155mm guns were made. The first was the M12, which was simply the old M1917 gun and its top carriage mounted on the rear of a stripped-down M3 medium tank chassis. Development was resisted by some elements of the Army and although they were built in 1942, it was not until mid-1944 that they were eventually issued. Some 76 were used in Europe, proved to be invaluable and served throughout the war.

Late in 1943 a fresh design, using the M1 gun, was begun, but this, again, was resisted by Army Ground Forces and it was not until early 1944, with the Invasion in sight, that work began again and it was April 1945 before the design was standardized as the SP M40.

Both the towed M1 and SP M40 were taken into British service and remained in use until the 1960s, and they were also supplied to other countries. The M40 is now entirely obsolete, but Japan, Jordan, Pakistan, South Korea, Turkey and a few other countries still use the M1. It is still a perfectly serviceable weapon, but the gradual improvement of the 155mm howitzer has led to its general replacement and it must now be considered a dying breed. The less difficult ballistic characteristics of the howitzer make ammunition design far easier – it is doubtful if modern smart projectiles could survive being fired from the 155mm gun – and improved howitzer ammunition has led to the gun's range advantage being quickly overtaken.

The US 175mm Gun

Design of this weapon began in the early 1950s with a demand for a group of heavy weapons capable of being transported by air; we need not dwell upon the various shifts and changes of design, but merely say that the 175mm Gun M107 and the 203mm Howitzer M110

(below) were eventually placed in service in 1963. The chassis was of armour steel and had torsion bar suspension, but was simply a hull upon which the gun mounting was placed; there was no protection for the weapon or the detachment, only the driver being under armour. Nor was there much room on the vehicle; only five men of the detachment and two rounds of ammunition could be carried, the other seven men and the rest of the first-line ammunition being carried in an accompanying cargo carrier. The gun had hydraulic power for elevation and traverse (which was restricted to 30° left and right of the centre line) and a complex ammunition hoist-cum-power rammer. Only one projectile was ever provided, a conventional high-explosive shell weighing 67kg, with which the gun could range to 32,700 metres.

The M107 was adopted by the US Army, Britain, West Germany, Israel, Greece, Spain, Turkey, Iran and South Korea. It was used quite extensively in Vietnam, and it soon became apparent that there was something radically wrong somewhere. Premature detonations and explosions in the barrel became too common for comfort, and eventually the defect was traced to certain features of the ammunition. The cartridge was redesigned, and the filling of shells more stringently examined; indeed, the West German Army emptied all its shells and had them refilled in Germany, since it found that shipping the ammunition from the USA to Europe in hot weather frequently caused the explosive to soften and shift inside the shell, causing air spaces which collapsed on firing with dangerous results. Even so, the gun was not well liked, and by the late 1970s the US Army was converting all its M107s by removing the barrels and replacing them with 203mm barrels, turning the equipment into M110s. A similar course has been followed by most other owners of these weapons.

The US 203mm (8in) Howitzer

Another elderly design, this was first mooted in the wake of the First World War, the intention being to develop an 8in howitzer and a 155mm gun which could

◄ A 175mm gun wrecked by the premature detonation of a shell in the barrel.

► The US 203mm howitzer M115 with British Army detachment.

share the same mountings. A design was perfected in 1920, but the inevitable shortage of funds closed the project down in 1921. The idea was revived in 1927 and after much juggling the final result was standardized as the 8in Howitzer M1 in 1940. The weapon used the same breech mechanism as the 155mm gun and fitted on to the same split trail carriage, though the interchange was not quite so simple as some people assumed. The howitzer was of different length, weight and recoil characteristics from the gun, and it was necessary to remove the top carriage and adjust the number of Belleville springs which supported the traversing racer. The equilibrator and recuperator pressures also had to be adjusted, and, in general, the change was not one that could be accomplished easily in the field.

However, the 8in soon acquired a reputation for phenomenal accuracy, which it retains to this day and which may possibly be one of the reasons for its retention. It fired a 200lb (91kg) high-explosive shell to a range of 16,925 metres, and no other type of shell was adopted. It was widely used during the Second World War by the USA and Britain and retained in service since, as well as being distributed to several other countries.

Development of a self-propelled version began in 1943, but the usual wartime lack of enthusiasm for heavy tracked weapons delayed development and it was not until 1946 that the SP M43 entered US service. As with the towed equipments, so with the SPs – the M43 was simply the 155mm M40 equipment but mounting the 8in instead of the 155mm tube. It was not so common as its 155mm partner, and was eventually replaced in the 1950s with the M55 version, again a partner to the M53 155mm weapon, both of which were enormous turreted equipments built on the modified M48 tank chassis.

The M55 was incapable of being airflifted, and since US Army doctrine of the 1950s relied heavily upon air transport, there came a demand for new SP guns, already discussed in dealing with the 175mm M107. The 8in M110 was the result of this and was simply the standard 8in upper carriage mounted on the same lightweight chassis that was carrying the 155mm and

◀ An 8in (203mm) M110 howitzer in Vietnam in 1969; this is typical of the series of SP guns developed in the USA when lightness and air-portability was at a premium. Protection for the men or stowage space for ammunition was scarcely considered.

▶ 203mm M110A2 howitzers of the British Army driving past at a review held before the Captain-General, Royal Artillery, HM Queen Elizabeth II.

175mm guns. Design began in 1956 and was standardized in 1961, the first service issues taking place in 1963. About 750 were acquired during the 1960s, and a further 209 of the A2 version were ordered in 1978.

Apart from its airportability, the M110 offered no advantage over the towed M1 equipment; it still fired the same 90kg shell at a muzzle velocity of 594m/sec to a maximum range of 16,932 metres, and in 1969 the US Army initiated the design of the M110A1 which was to have a greater range. This was standardized in 1976 and entered service in the following year, the existing M110s being converted to the M110A1 specification at a reputed cost of just under $100,000 each. The additional range (21,300m) was achieved by fitting a longer barrel, and a new and improved series of projectiles was also developed. But the M110A1 had scarcely been in service a year before it was improved into the M110A2 by the addition of a muzzle brake, which allowed the firing of a heavier propelling charge and thus lifted the range to 24,000 metres with conventional shells and 29,100 metres with rocket-assisted shells.

The principal role of the 203mm howitzer is as a tactical nuclear delivery system, using the M422 or M753 AFAP (Artillery-Fired Atomic Projectile). The M422 can be fired by any of the 203mm family and can be configured in either 12kt or 0.5kt versions to suit target requirements. It uses Uranium 235 as the fissile material. The M753 shell can only be fired from the M110A2 howitzer and uses a W79 Plutonium 239 warhead; its yield is not disclosed.

As well as being in US service, the M110 is widely used throughout NATO (generally in M110A2 configuration) and in the Middle and Far East.

The FH-70 Consortium

During the early 1960s Britain, West Germany and the USA agreed that they needed a new 155mm towed howitzer; the USA and Germany wished to replace their M114 weapons and the British their 5.5in gun. As with so many of these multi-national efforts, the whole thing fell apart since the Americans were insistent that

the weapon be airportable while the Europeans were more concerned with improving the ballistic performance. Eventually the parties agreed to differ and the US went on to develop their M198 towed howitzer, while in 1968 the British and Germans agreed to develop a new weapon to be called FH-70 (for Field Howitzer of the '70s). The three basic requirements were improved range and lethality with a new family of ammunition, a high continuous rate of fire plus a burst-fire capability, and good mobility with minimum effort for deployment.

The first six weapons were built in 1969–70, whereupon Italy joined the consortium. More prototypes were built and tested, and finally a complete trials battery of six howitzers was formed in 1975. The design was accepted for service in the following year and the first issues to service regiments took place in 1978. The development cost £30 million, and each equipment, in 1976, was said to cost £300,000. As well as being adopted by the three NATO partners, Saudi Arabia has bought a large number and it has been tested by several other armies.

The components of FH-70 were parcelled out among the participants; Britain produced the carriage and traversing gear and the HE shell and propellant charges; Germany produced the ordnance and breech mechanism, loading system, auxiliary propulsion unit, suspension and sights and were responsible for the smoke and illuminating shells and propellant charges. Italy produced the cradle, recoil system, sight bracket, elevating gear and arc, high-explosive, smoke and illuminating shells and propellant charges. The various components were shipped around Europe and final assembly was done in each country, the export manufacture being done in Britain. In more recent years the Japanese Self-defence Force has adopted the FH-70 and production has taken place under licence in Japan.

FH-70 is a conventional howitzer using a 39-calibre barrel with muzzle brake and an upward-moving vertical sliding breech-block with ring obturation. Elevation and traverse are manual, with a quick-release which allows the barrel to be swung through 180° to clamp over the trail legs in the travelling position. The trail is a split pattern with two main

▶ The 155mm FH-70 howitzer in firing position.

wheels and two small trail dolly wheels. The auxiliary propulsion unit is carried ahead of the main wheels and consists of a Volkswagen 1,800cc engine which drives the main wheels through a gearbox and differential, and also drives an hydraulic pump which provides power for steering (via the trail wheels) and raising and lowering both main and trail wheels. By using the hydraulic system the trail can be lifted so as to unhook from the towing vehicle, the main wheels lifted so as to lower the howitzer on to its firing pedestal, and, by manipulation of the trail wheels, the trail load can be lightened so as to facilitate opening the trail by hand. Once the gun has been fired the hydraulic lift on the trail wheels can also be utilized to clear the spades from the ground.

The sighting system depends upon the user country; in British service the howitzer is fitted with the usual panoramic sight and direct-fire telescope, quadrant elevation scale and levelling bubbles. But the sight carrier incorporates transducers for elevation and azimuth, and in German and Italian service these are connected to a digital display unit which also receives firing data from the fire control computer.

The standard projectile is a hollow-based shell of excellent ballistic shape, and it is propelled by an eight-zone combustible cased charge system initiated by a

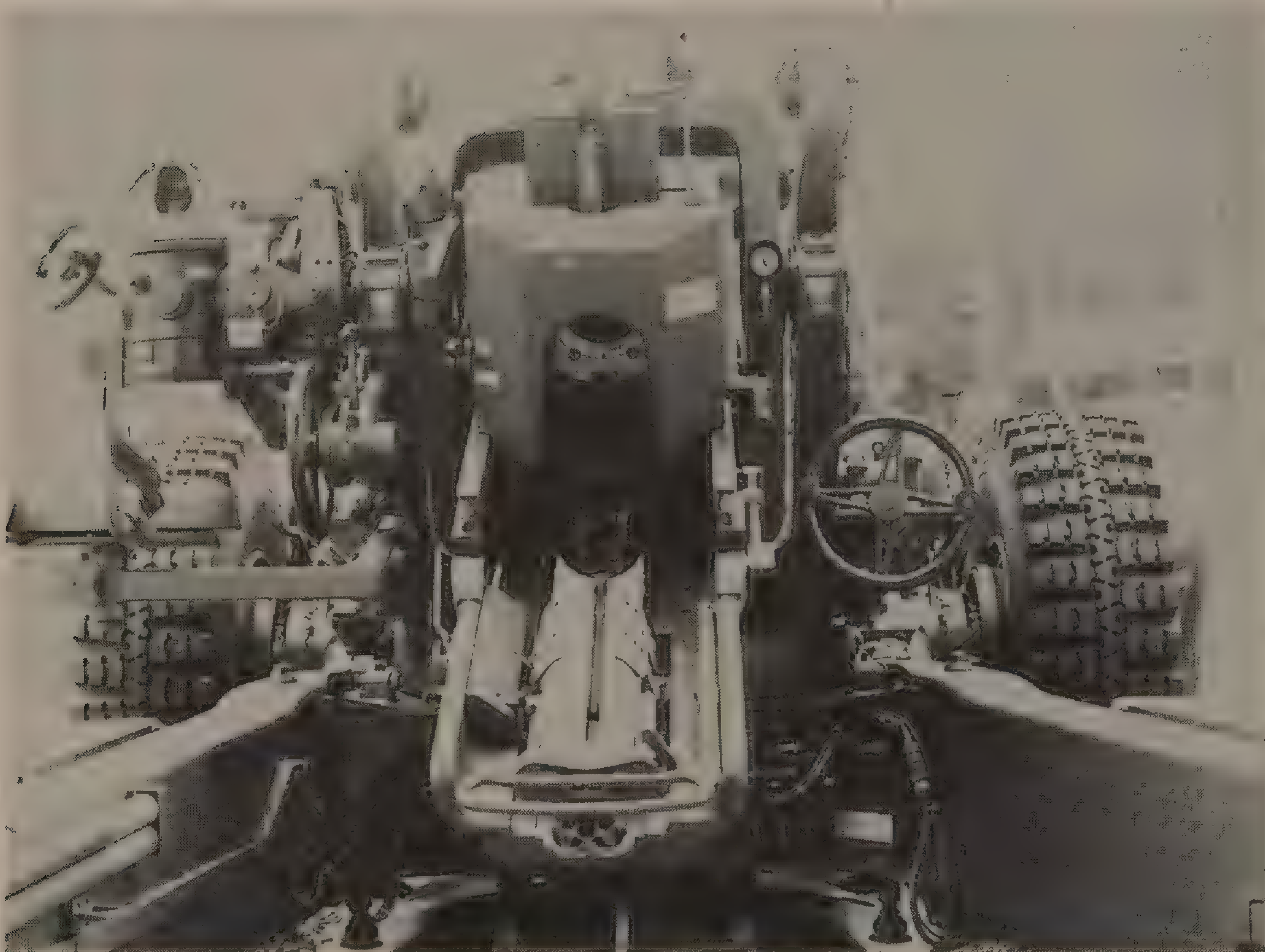
percussion primer. The muzzle velocity ranges from 213 to 827m/sec, giving the 43.5kg shell a maximum range of 24,700 metres. Using the US M549A1 rocket-assisted shell increases the range to just over 30,000 metres, while an ERFB-BB (Extended Range, Full Bore, Base-Bleed) shell with special charge extends the maximum range to 31,600 metres.

Operation of the weapon is relatively simple. Once the howitzer has been emplaced, the breech has to be opened by hand and the first shell and charge hand-loaded; the second shell is placed on the loading tray and the breech is closed, automatically loading a primer into the lock from an 11-primer magazine. After firing, the ordnance recoils, and during run-out the breech is automatically opened, the fired primer is ejected and the loading tray lifted so as to align the next shell with the chamber. This shell is hand-rammed and the cartridge hand-loaded, the breech closed, loading a fresh primer, the next shell placed on the retracted loading tray and the gun is ready to fire. A flick rammer is available whch allows a burst of three rounds to be fired in just under fifteen seconds.

There has been surprisingly little modification to FH-70 since its introduction, indicative of sound design in the first place. In 1984 the German firm Rheinmetall, who were the German manufacturers, developed a new 46-calibre barrel with a larger chamber which allows the standard HE shell to reach 30,000 metres' range; this has been tested and shown to be satisfactory and, as the FH-70R, is currently being considered for adoption by the Bundeswehr.

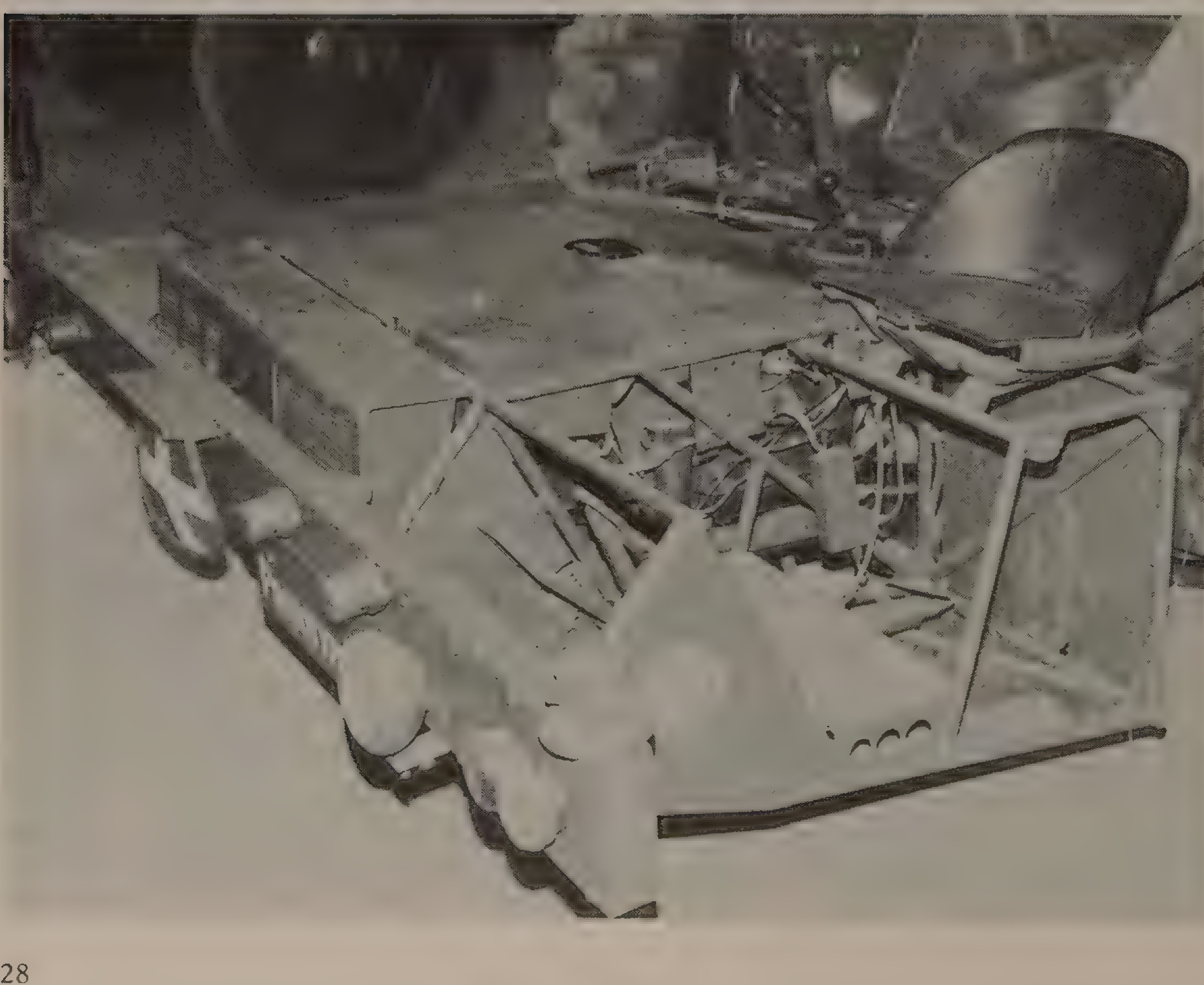
The major development from FH-70 was SP-70, a self-propelled version, which began in 1973. In brief this was to be the FH-70 ordnance with a mechanized loading system mounted in a turret on a tracked chassis developed using components of the Leopard tanks. Germany was the project leader and Britain and Italy participated, sharing out the development of components as before. A most involved development programme was drawn up, involving batches of prototypes, and the first trials of equipment took place in 1979. Thereafter the project gradually slipped farther and farther back and the whole thing went down the drain until in late 1987 it was abandoned, several hundred millions of pounds, Deutschmarks and lire having gone with it. Charges and counter-charges were made, tempers flared, but the inside story is unlikely to be known for many years yet.

From a gunner's point of view (which appears not to have been a point of view often called for during the development of this weapon) the whole project was far too ambitious, with too much new and untried technology being incorporated in the hope that the sum would be greater than the parts. The soldiers appear to have had little faith in it after the initial euphoria had worn off; by the late 1970s they were referring to it as SP90, and by 1984 it was cynically known as 'SP2000'. Its abandonment has thrown the erstwhile partners back on to either their own resources or on to the American market, and we shall discuss the various national choices later.



◄ The open breech of the 155mm FH-70 howitzer; the firing platform can be seen below the cradle, which carries the rapid loading apparatus.

► Towing the 155mm FH-70 howitzer over rough country. (Vickers Shipbuilding & Engineering)



◄ Typical of auxiliary propulsion units, this is the APU of the 155mm FH-70 howitzer.

▶
Firing the FH-70.


03DA25

The British 105mm Family

In the mid-1950s the British Army had more or less decided upon its new field gun; it was to be an 87mm weapon firing a 25lb shell, but with better performance and lethality than the existing 25pdr gun. It had a most unusual carriage, with a box trail which rose into the air behind the gun before reaching the ground, and this supported a glass-fibre umbrella-type shield which acted as protection against nuclear flash and radiation. At the same time an entirely new 5in mortar was entering the final stages of its development.

Overnight, the requirements changed; NATO agreed upon 105mm as the standard close support calibre. Out went the 87mm gun and the 5in mortar, self-propulsion was the order of the day, and to fill the gap until a home-designed SP equipment could be made, the Italian 105mm M56 pack howitzer was purchased.

One thing was settled very early in the proceedings; that the 105mm ammunition would not be the universally employed American M1 family. This was, after all, of early 1930s design and modern technology could improve upon it in several directions. So a completely new family of ammunition was developed and then the gun to fire it. The new projectile was longer and better shaped than the M1 and weighed 16.08kg. Of high-tensile steel and filled with RDX/TNT, it gave a 25 per cent increase in lethality over the M1. The propelling charge system used a much larger case, with electric primer, and there were eight charges; the highest, Charge 6, was a single charge in its own case. Charges 1 to 5 had their own case and were contained in cloth bags, which could be removed as desired to change the charge zone. Charges A and B were special short-range 'mortar' charges; the standard case would be emptied of its bags and the A or B bag inserted so as to reach ranges between about 2,000 and 4,500 metres. In practice, the Charge A proved unreliable, being erratic in velocity and occasionally failing to get the shell as far as the muzzle and its use was abandoned.

The gun evolved around this ammunition was a 37-calibre with fume extractor, muzzle brake, and vertical sliding block semi-automatic breech. This was mounted in a turret giving 360° traverse and 70° elevation, which, in turn, was carried on a chassis assembled from the standardized components of the FV430 series of light armoured vehicles, the new design becoming FV432 or 'Abbot'. (There is a tradition of ecclesiastical names for British self-propelled guns, dating back to the 'Bishop' and 'Sexton' of 1942.) Manned by a four-man detachment (driver, commander, layer and loader), Abbot can propel its shell to a maximum range of 17,300 metres and is quite agile across country.

Development of Abbot began in 1958; the prototype was completed and tested in 1961 and it went into service in 1965, but within ten years the policy had changed and there was general agreement among NATO that 155mm had to be the standard support calibre. Abbot, therefore, was scheduled for replacement by SP70 after about 15 years of service life, but, as we have seen, SP70 failed to materialize and Abbot has therefore had to continue in service longer than anticipated. It is now hoped that its replacement by the 155mm howitzer AS-90 will take place before 1995.

Abbot was an excellent weapon and generally well-liked; it had, though, one defect in the eyes of the planners, and that was its inability to be easily air-lifted. The 105mm Pack Howitzer could be lifted beneath helicopters, but what was wanted was a lightweight field piece which could take advantage of the new Abbot ammunition. In 1965, therefore, with Abbot starting to appear in service, design began on adapting the Abbot barrel geometry to a wheeled carriage. Lightness being the principal aim, the trail was a bowed structure of tubular sections, above which was a top carriage supporting the light, skeletal, tubular cradle. The hydro-pneumatic recoil system cylinders are disposed around the cradle, and there is a cut-off gear which reduces the recoil stroke as the gun is elevated. The gun is similar to that used in Abbot, but without the fume extractor, and the electric power for firing is derived from an impulse magneto. A spade is fitted, and there is a light platform carried on the trail which can be placed on the ground and the gun run on to it to permit easy traverse.

One wheel is fitted with a quick-release mechanism. When travelling, the gun barrel lies over the trail legs, and to bring the gun into action the wheel is jacked up and removed, the gun swung round to the firing position, the wheel re-attached and the jack removed. The reverse procedure allows the barrel to be returned to the travelling position. It sounds cumbrous but is, in fact, an easy and quick operation.

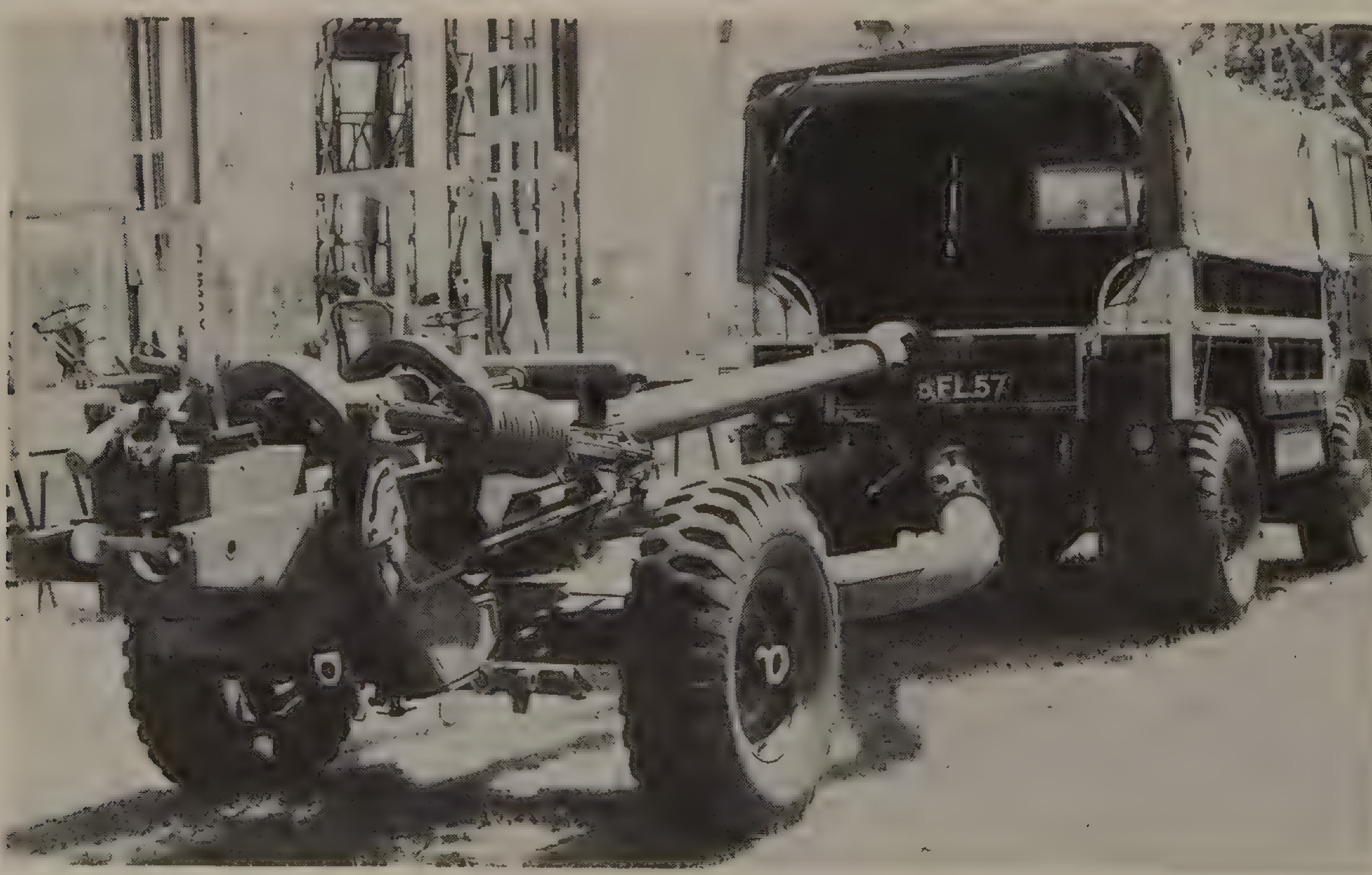
◄ The 105mm Abbot self-propelled gun at maximum elevation.

The resulting 'Light Gun L118' weighs 1,860kg and can be carried slung beneath a Puma or similar helicopter. The design was completed and trials were held in 1972, the gun being formally introduced on 25 October 1974. Since that time several hundred have been built and it is now in service with Britain, Australia (where it is manufactured locally), New Zealand and the USA as well as several Middle Eastern and African countries.

In view of its likely employment by rapid intervention forces, it was decided to develop two barrels for the Light gun; the L118 gun, as we have seen, uses the same ammunition as Abbot to achieve the same performance. The alternative barrel is chambered to

◄ The Light Gun was designed with air-portability in mind; here the gun is being delivered by a Puma helicopter.

► Airborne gunners firing the 105mm Light Gun.



◄ The 105mm Light Gun on tow, showing how the barrel is locked over the trail for travelling. Note, too, that this gun is without its platform.

accept American M1 ammunition, with which it can reach a maximum range of 11,700 metres. It differs not only in chamber contour but in rifling, being progressively rifled from one turn in 35 calibres to one in 18, and in having a single-baffle muzzle brake instead of the L118's double-baffle pattern. The two barrels can be quickly interchanged, and with the 'Americanized' barrel the gun is known as the L119. The batteries forming part of the Allied Commander Europe's Mobile Force actually have guns with both barrels, so that they can go to their designated destination with the barrel appropriate to the local ammunition supply. And, of course, the guns purchased by the USA (as the M119) are barrelled for American ammunition.

The Space Research Corporation Designs

During the late 1960a the Space Research Corporation (SRC) of Quebec began the development of a 45-calibre 155mm howitzer and an entirely new projectile. The gun, apart from its chamber contour and rather deep rifling, was of conventional design, but the projectile was quite novel. The 'Extended Range, Full Bore' (ERFB) shell was somewhat longer than normal and had a long and gradual taper from just in front of the driving band, rather than having a parallel-walled section, hitherto considered necessary to give adequate bearing and support in the barrel. Instead, the ERFB shell had 'nubs', small aerodynamically shaped stub wings (for the want of a better term) formed on the forward part of the body, more or less where the shoulder of a normal shell would have been. These 'nubs' were canted to the same angle as the rifling, but had their tips formed into a bearing surface rather wider than any one groove so that they rode on the surface of the bore as the shell travelled up the barrel, centering the shell and supporting it. In flight, the aerodynamic section gave the projectile a degree of lift, so extending the range beyond that which would be considered normal for a conventional projectile of the same weight. The ERFB title was given in order to emphasize that the range was achieved without resort to discarding sabot techniques.

The activities of SRC over the next few years were beset with problems; there were accusations of breaking the arms embargo on supply to South Africa, there were tales of dubious transactions with foreign countries, and the whole business became most convoluted and mysterious. Eventually, in the mid-1970s, SRC Quebec folded and the guiding hands moved to Belgium to co-operate with the Belgian company PRB SA to set up a new company called SRC International. Here the new company carried on the work begun in Canada and in 1977 produced the first GC-45 howitzer. Two were produced and assembled in Canada; the parts for a further ten were made in Canada and then shipped to Austria where they were assembled by Voest-Alpine, and the entire batch of twelve were then supplied to Thailand.

The GC-45 gun-howitzer is a split-trailed, four-wheeled bogie weapon with the gun mounted on a top

◄ The British 105mm Light Gun L118 on its firing platform.

carriage which can be rotated to lock the barrel over the trail for travelling. The gun has an enlarged chamber; it can fire NATO-standard ammunition at the velocities and ranges achieved by 39-calibre weapons due to the air-spacing effect of the normal charges and large chamber, and it can fire ERFB projectiles using appropriate heavier charges. Using ERFB projectiles it can reach a maximum range of 30,000 metres, and using ERFB base-bleed (ERFB-BB) shells it can reach to 39,100 metres.

Only twelve GC-45 guns were made, and the design can be considered obsolescent, but it is of interest as the progenitor of several guns that were either developed from or inspired by it. SRC International went on to operate as a design consultancy and project management agency for a number of artillery developments in various countries until 1986, when it associated itself with some Spanish companies and went into the development of new weapons, which will be considered shortly.

In 1979 Voest-Alpine, the government-owned Austrian steel company, began developing a new 155mm howitzer using the SRC International GC-45 as their starting point. A licence for manufacture of the GC-45 was obtained, and their first venture was the construction of ten weapons, from parts made in Canada, for supply to the Royal Thai Marines, as noted above. Once this was done, Voest set about redesigning the weapon to make production easier – they made more than 100 changes in the design – after which, under the designation GH-N-45, more than 300 more guns were built for sale to various countries (principally Iraq and Jordan) as well as a small number for adoption by the Austrian Army.

The GH-N-45 155mm gun-howitzer is a towed equipment; suspension is by four wheels, two each side of the carriage carried on walking beams. The trail legs, when closed, are hooked to the towing vehicle. The gun is carried on a top carriage which can be rotated through 180° so as to align the barrel over the trail for travelling. The barrel moves in a ring cradle with a split hydro-pneumatic recoil system, the cylinders of which are above and below the cradle. There is a hydro-pneumatic balancing system based on that used with the US 155mm Gun M1, two cylinders which lift the cradle so as to counter the muzzle preponderance.

The gun uses a screw breech with semi-automatic operation, and has a percussion firing lock. There is a pneumatic flick rammer which is kept charged by an additional cylinder in the recoil system. The barrel is 45 calibres long and has a large chamber which permits the firing of a heavy maximum charge. It will fire all NATO-standard (M107) 155mm ammunition, but is particularly designed to fire the EFB (Extended Range, Full Bore) projectiles originally developed by SRC International and PRB of Belgium and improved upon and manufactured by the Austrian Hirtenberger company. These projectiles, described elsewhere, give the GH-N-45 a range of 30,000 metres when fired with the heavy charge, and using base-bleed projectiles the gun can reach a maximum range of 39,500 metres. The Austrian Army, however, are forbidden to use base-bleed by some obscure interpretation of the Peace Treaty restrictions.

The towed version of the gun is fairly conventional except for a rather unusual linkage between the trail legs and the wheels which allows the carriage to follow exactly in the tracks of the towing vehicle. There is a firing support beneath the main carriage which can be quickly lowered to give a stable mounting, and the whole carriage is so well-balanced that in an emergency it can actually be brought into action by two men.

More interesting is the auxiliary-propelled version. The power pack can be built into an original gun or can be retro-fitted to an existing weapon. It consists of a Porsche 4-cylinder engine which drives an hydraulic pump to provide power for hydrostatic motors on each wheel. The engine is mounted ahead of the top carriage, in the usual manner, complete with driver controls; there are two castor wheels under the trail ends and the auxiliary-powered gun can reach a speed of 30km/h on a good surface. Moreover the propulsion system can be switched in, from the cab of the towing vehicle, to provide additional traction in difficult ground.

Additionally the APU version of the gun can be fitted with power elevation and traverse, tapping the power from the hydraulic system, and with a powered ammunition hoist.

China has connections with SRC International though these appear to be entirely technology transfers. In 1986 the Chinese revealed a new 152mm weapon which, it was reported, had been built using a number of components of the GH-N-45 howitzer purchased from Voest-Alpine in Austria. The weapon bears considerable resemblance to the Austrian/SRC design, having a split trail and 45-calibre barrel with muzzle

brake. However the gun uses a horizontal sliding block breech mechanism with a cased charge, the breech being developed from the existing Type 66 152mm howitzer, itself a derivative of the Soviet 152mm D-20. The new weapon, reputedly known as the 'WAC-21', fires an ERFB projectile and possibly an ERFB-BB as well. It is known that a base-bleed shell has been developed for the standard 130mm gun (another Soviet copy).

The South African Connection

As noted above, at one stage of their career SRC of Canada were accused of supplying howitzer components to South Africa. The South Africans have always denied this, and whatever the truth of the matter it is of little consequence here. but in 1982, at the first 'Defendory' arms exhibition to be held in Athens, Armscor, the quasi-governmental South African armaments consortium, exhibited a 155mm howitzer which surprised the rest of the world and suggested that whether or not they had obtained equipment from SRC they had certainly adopted many of SRC's ideas.

During operations on the Angolan border in 1974–5 the South African Defence Force found that its existing artillery, mainly the British 25pdr gun and 5.5in howitzer, was severely outranged by the Soviet armaments fielded by the Angolan forces. Artillery staffs drew up a comprehensive specification calling for a new gun, towing vehicle and fire control system and then asked the Armscor to build something to fit.

They began by making a gun based more or less on the GC-45 design, fitting it to an old US 155mm Gun M1 mounting; this progressed through another six developmental models before the work culminated in the G5 howitzer, which went into South African service in 1983. According to South African sources the development that went into the G5 has meant that very little of the original GC-45 design remains, the majority of the weapon being of entirely South African inspira-

▼ The South African 155mm G5 howitzer with its tractor.

tion and design; and having examined the weapon closely I am inclined to agree.

The G5 is a 45-calibre weapon designed to fire ERFB projectiles. It has a multi-baffle muzzle brake and a semi-automatic screw breech similar in appearance to that used on the American M198 howitzer, though using an Asbury mechanism rather than the antiquated 'slow-cone' design used by the Americans. Behind the breech is a pneumatic rammer for shells; the bagged charges are hand-loaded. The carriage uses a four-wheeled bogie and split trail, and the gun is carried on a top carriage with hydro-pneumatic balancing gear and an openwork cradle with the recoil system split above and below. There is an auxiliary propulsion unit ahead of the bogie, providing power for movement, raising and lowering the trail dolly wheels, opening and closing the trail legs and raising and lowering a firing platform carried beneath the fore carriage, between the bogie wheels. For travelling, the barrel is swung through 180° and clamped to the trails, and the gun is then towed by a 6 × 6 truck. The truck also carries the eight-man gun detachment and fifteen pallet-loads of ammunition.

The standard projectile is an ERFB HE shell weighing 45.5kg and having a muzzle velocity of 897m/sec at top charge, giving a range of 30,000 metres. An ERFB base-bleed shell increases this range to 39,000 metres. Smoke and illuminating shells are also available and it is believed that an ICM loaded with mines or anti-personnel bomblets is under development. The base-bleed, although doubtless based on published information from outside South Africa, is an entirely local design, and the SADF point out that they are the only army to have actually deployed a base-bleed shell in operational use, and with considerable effect.

The northern border of South Africa/South West Africa, from Oro Point on the Indian Ocean to Foz da Cunha on the Atlantic is about the same distance as from London to Moscow, and the only access to most of it is by road, where roads exist. The bush and desert country of most of the border places severe demands upon military vehicles, so that when the South African Army began contemplating a self-propelled version of the G5 howitzer, there had to be rather more to it than seeking out a redundant tank chassis and bolting a gun on top of it. A conventional tracked SP gun could well wear out its tracks in the approach march, before it ever got within shooting range of an enemy, and the complex and special mechanical arrangements common to tanks would place an intolerable burden upon the logistic services. The solution adopted was that of a wheeled SP howitzer, which became known as the G6 and was first seen in 1983.

The wheeled solution is a very valid one; wheeled vehicles demand less complicated mechanical arrangements, use 60 per cent less fuel, have more than

◀ The South African 155mm G6 wheeled, self-propelled howitzer.

sufficient cross-country ability for bush and desert terrain, have three times the life and are some 50 per cent cheaper in first cost than tracked vehicles. Whether they would be as valid in a European urban scenario is a different question (although the Czechs seem to think they are, as we shall see), but the South Africans were not designing for Europe. The G6 is a sizeable vehicle, well armoured, with the howitzer turret-mounted and with the same ballistic performance as the G5. Although the turret can traverse 360°, firing is only permitted within a restricted frontal arc of some 80°; broadside-on firing could well tip the vehicle over, in spite of stabilizing supports. The vehicle is a six-wheeler with armour capable of defeating 23/25mm cannon projectiles as well as small arms and shell fragments. The five-man gun detachment ride in the turret, and the driver is in his own small compartment in the front of the vehicle, with the air-cooled diesel engine between him and the turret. In front of the driver is a massive wedge-shaped prow which acts as an ammunition store (holding twelve rounds) and also as a useful bush-clearing blade capable of demolishing small trees.

As well as equipping the South African Defence Force, the G5 has been sold abroad, though the identity of the clients has never been officially disclosed. It is known, however, that Iran has some of these weapons, and others are believed to be in use in various Far Eastern countries. In March 1989 the Chilean company Cardoen Industries announced that they had concluded an agreement with Armscor to manufacture the G5 in Chile and that, indeed, the first locally-produced G5 had successfully completed trials. An agreement to co-produce the G5 was expected to be announced later in the year. Chile claims that their manufacturing costs will be lower than South Africa's, due to lower labour costs and various tax and economic advantages, and they will, of course, have the ability to sell in countries that cannot deal with South Africa due to political inhibitions. Cardoen have said that they foresee sales of more than 400 guns within the next three years.

The GIAT Howitzers

The French, to their credit, do not contemplate expense too closely when a piece of military equipment is required; what they are more concerned with is that the maker's nameplate on the equipment should be a French one. So that when the army decided that it required a pair of 155mm howitzers, one towed and the other self-propelled, there was no inclination to rush off and buy the M114 and the M109.

The French Army had, not unreasonably, been re-equipped with much American equipment in 1944–5, but by the early 1950s they had developed their own 155mm SP gun, the F3. This was a simple but effective weapon, based on the stripped-down chassis of the AMX13 tank, and it bore some broad resemblance to the US 155mm howitzer M41, merely a naked gun clamped to the top of a tracked hull. But by the late 1960s it was beginning to feel its age, and its maximum range of 20,000 metres, although better than many rivals, was not good enough. (And with their obsolescent weapon ranging to 20,000 metres there was even less likelihood of buying American when the current M109 could barely manage 14,000 metres.)

In 1969, therefore, the Army formally stated a requirement to GIAT – the Groupement Industriel des Armements Terrestre, the French governmental consortium of defence establishments more or less the equivalent of the Royal Ordnance Factories organization of the same period. GIAT parcelled the task out to various French establishments, the project being generally under the control of EFAB – Etablissements Fabrication de l'Armement de Bourges, the long-established French gun factory, and the resulting weapon, the 155mm GCT (Grand Cadence de Tir) self-propelled gun was completed in 1972. During the following five years ten pre-production vehicles were built and thoroughly tested, and in 1977 the design went into production.

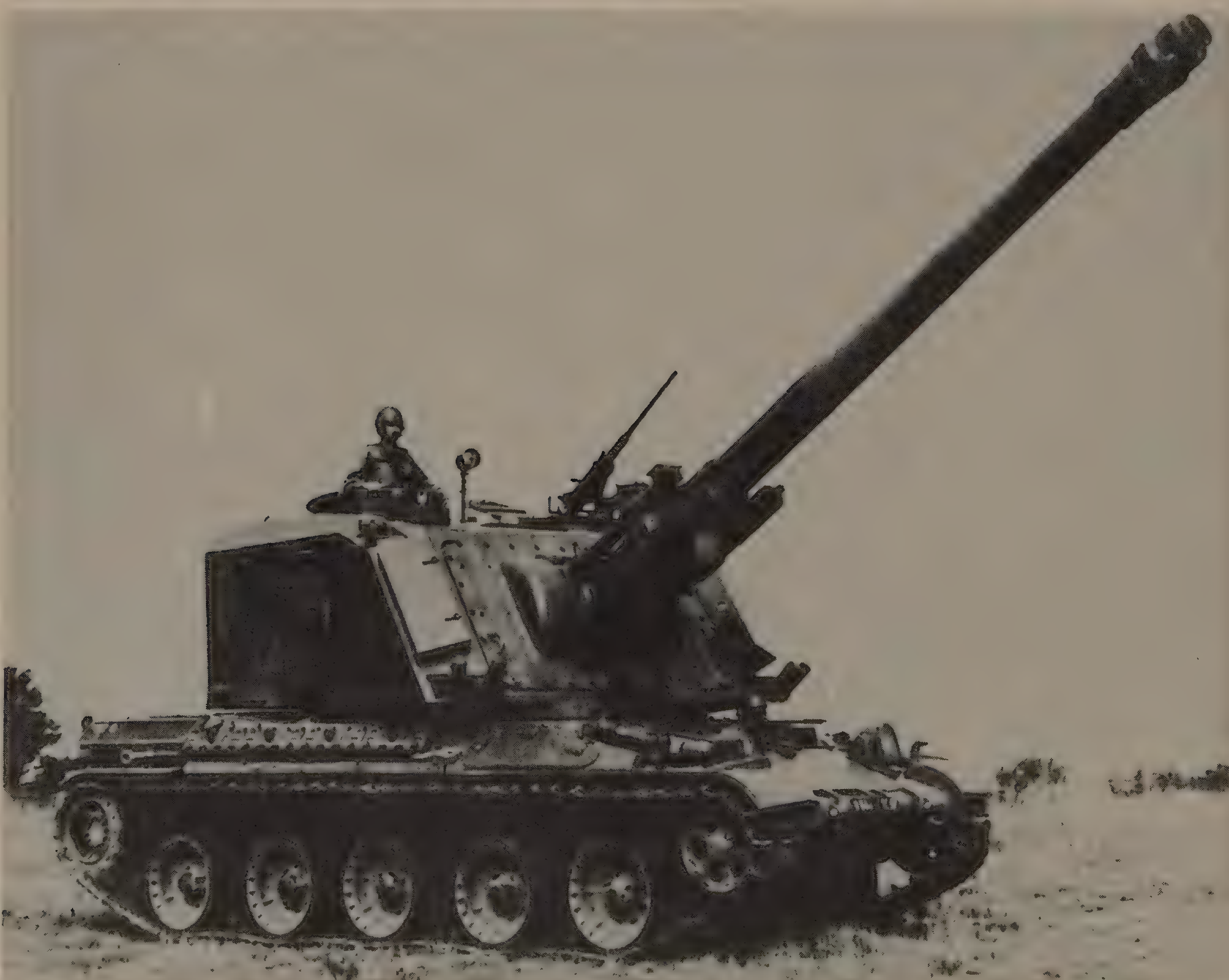
This appears to have taken the French Army by surprise, since they had apparently not budgeted for the gun's appearance before 1979, and so the first production weapons were sold to Saudi Arabia in 1978. In the following year it was formally approved for service with the French Army, and deliveries to troops began in 1980. A total of 190 were ordered, and all have now been delivered. In addition, 51 have been sold to Saudi Arabia and 85 to Iraq.

The GCT may look a ponderous weapon, with its enormous turret, but the designers refused to be beguiled into making it look like a tank and as a result there is ample room inside for mechanical ingenuity which can thus be built big enough to be reliable. Despite its size it is operated by a four-man crew – commander, driver, gunner and loader – any two of

which are quite capable of operating the weapon while the other two rest.

The rear of the turret is occupied by racking for 42 projectiles and 42 combustible cartridges, plus a mechanical handling system. The gunner sits on the right-hand side, operating the sights and gun controls, while the loader sits on the right, facing a control panel which indicates the status of the ammunition racks, and controls the handling devices. The gun breech is between and well below the two men, quite isolated from them, since there is no need for them to touch the breech at all, due to the mechanical loading arrangements.

On being given his mission orders, the loader simply selects, on his control board, the number and nature of shells and the cartridge required and pushes a button. The mechanical system picks the appropriate shell from the rack, conveys it to the breech, loads it and rams it. Hard on its heels comes another trolley carrying the cartridge, which is loaded and the vertical sliding breech-block closed. There is no need to load a tube (or primer) in this weapon, since ignition is performed by an induction coil set into the breech-block. A corresponding, smaller, coil is present in the rear of the cartridge, connected to a pyrotechnic squib. When the gunner presses the 'fire' button, an electric current is injected into the breech-block coil, and induces a current in the cartridge coil which thus fires the squib and ignites the cartridge. The gun fires, recoils, runs out, the breech



Forerunner of the GCT, the 155mm Mle F3 Automoteur.

The French 155mm GCT self-propelled howitzer, operated by three men and a driver.

opens, and by that time the second round has arrived and is rammed. The mechanical handling is so fast that six rounds can be fired in 45 seconds.

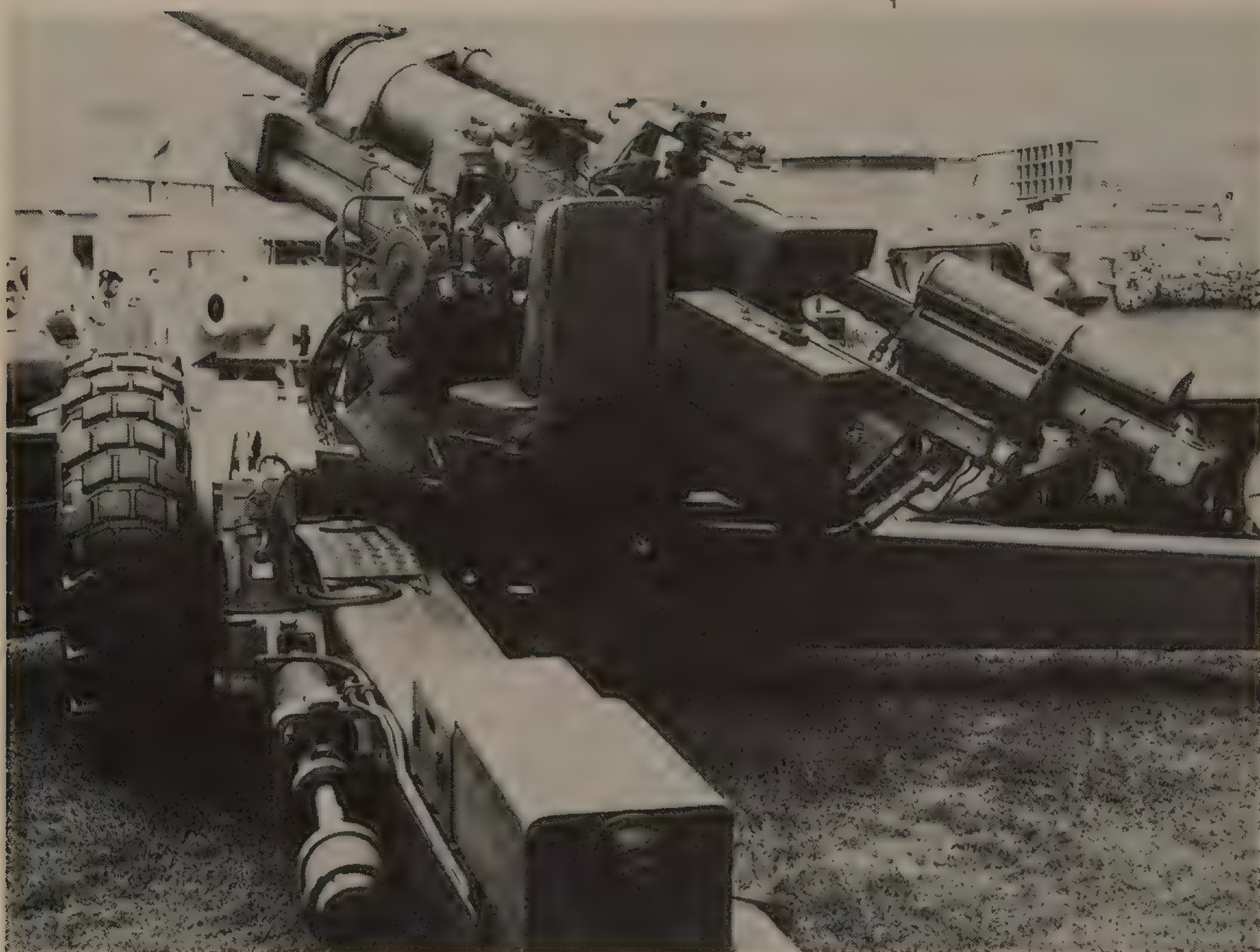
Considering that this form of induction firing was first tried by the Germans in 1944, and was well documented afterwards, it is rather surprising that nobody else has bothered to use it. It has some theoretical drawbacks relative to the presence of electromagnetic energy in the neighbourhood of the gun, but these are of little practical consequence, since the coils are never aligned until the breech is closed, at which time the gun is about to be fired anyway. And it certainly does away with the vexed question of automatic primer loading mechanisms, primer magazines, jammed primers and similar annoyances which occur from time to time on more conventional weapons.

The gun itself is a 40-calibre weapon with a muzzle brake; there is no fume extractor, since the gun breech is not in the same compartment as the operators, but there is an air blast through the breech ring to scavenge the bore and a forced ventilation system to remove any fumes from the breech area. The standard projectile is a modern hollow-base design weighing 43.5kg, which is fired at a velocity of 810m/sec to a maximum range of 28,500 metres. The howitzer can also fire older designs of projectile, though to a lesser range, and a rocket-assisted shell has a range of 32,000 metres. There is some evidence for the belief that the French take a somewhat jaundiced view of rocket assistance and are more interested in a workable base-bleed projectile which is likely to give the same amount of range increase with better accuracy and a better payload.

Once the self-propelled howitzer was under way, work began on the towed equipment, the 155mm TR (Tir Rapide) or 'Canon de 155mm Tracté'. Development began in the mid-1970s and the gun was first seen in 1979. Eight prototypes were built and tested over the next three years, production began in 1984, and the full quota of 79 weapons is now in service with the French Army.

The 155mm TR if of similar design to the FH-70 and other contemporary howitzers, a towed weapon capable of having the barrel swung round above the trail legs for towing and with an auxiliary propulsion cell in front of the two wheels. One novelty is that the wheels

▶ The French 155mm TR howitzer and (inset) the equipment in transit, with the barrel turned back over the trail legs.



◀ The breech end of the 155mm TR, with the power rammer aligned with the breech.

▶ A complex and expensive weapon, the Swedish 155mm Bandkanon in travelling order.

are actually suspended from the front ends of the trail legs, so that when the rails are opened the wheels go with them, rather than staying still and restricting the movement of the trail. The auxiliary propulsion engine is quite powerful and drives three hydraulic pumps, one each for the two wheels and one to provide power for elevation, traverse, raising the suspension, lowering the trail wheels and jacks and hoisting ammunition. The towing vehicle, a ten-tonne Renault truck, carries the eight-man detachment and 48 rounds of ammunition.

The gun is the same as that used with the SP GCT, the only change being that the breech mechanism is a horizontal sliding block rather than a vertical one and the induction firing system used on the GCT is replaced by a more conventional electric primer, complete with automatic loading mechanism attached to the firing lock. This is acceptable in this design since there is no difficulty in getting at the breech to load tubes or rectify problems; moreover it gives the gun a wider range of ammunition, since it is no longer restricted to the special induction-fired charges and can utilize older patterns of cartridge. The same hollow-based shell is fired, at 820m/sec muzzle velocity and a maximum range of 29,000 metres. A rocket-assisted shell is available, giving a range of 32,000 metres which, quite frankly, seems to be a poor return for what has to be given up in payload and accuracy. The gun can also fire the US M107 family of ammunition and NATO-standard FH-70 ammunition, a useful facility which means that in the event of war it can virtually be supplied from any NATO stocks.

The Bofors Family

'Bofors gun' means 'light anti-aircraft gun' to most people, but this ignored the long history of Bofors field and heavy artillery, specimens of which have armed armies around the world since the turn of the century, if not earlier. However, apart from designs for the Swedish forces Bofors had done very little in field artillery since the early 1930s, having specialized in anti-aircraft designs, and it was not until the late 1950s that, at the prompting of the Swedish Army, Bofors returned to the field artillery business with an advanced self-propelled gun known as the 'Bandkanon 1A'.

The Bandkanon was so advanced as to be out on its own in 1966 when it went into production, and in some respects it is still there. It was an extremely expensive weapon, since the number built for the Swedish Army was only 30 and it was never exported; so those 30 had to pay for the development, and each gun cost 2 million Kronor. Some economics were made by using components from the S-Tank (another highly advanced concept) for the chassis, but even with that the bill was steep.

Nevertheless, for the money the Swedes got what was undoubtedly the most advanced piece of artillery in existence at the time, and for several years afterwards. The gun sits above the chassis, which is provided with hydro-pneumatic suspension which can be locked solid for firing to give good stability. The 50-calibre gun has a muzzle brake and a loose liner, and is carried in what appears to be a turret but is actually two fixed cabins, the gun lying between them and capable of only 15° left and right traverse. Above and to the rear of the gun is a complicated girder structure which carries the ammunition loading system.

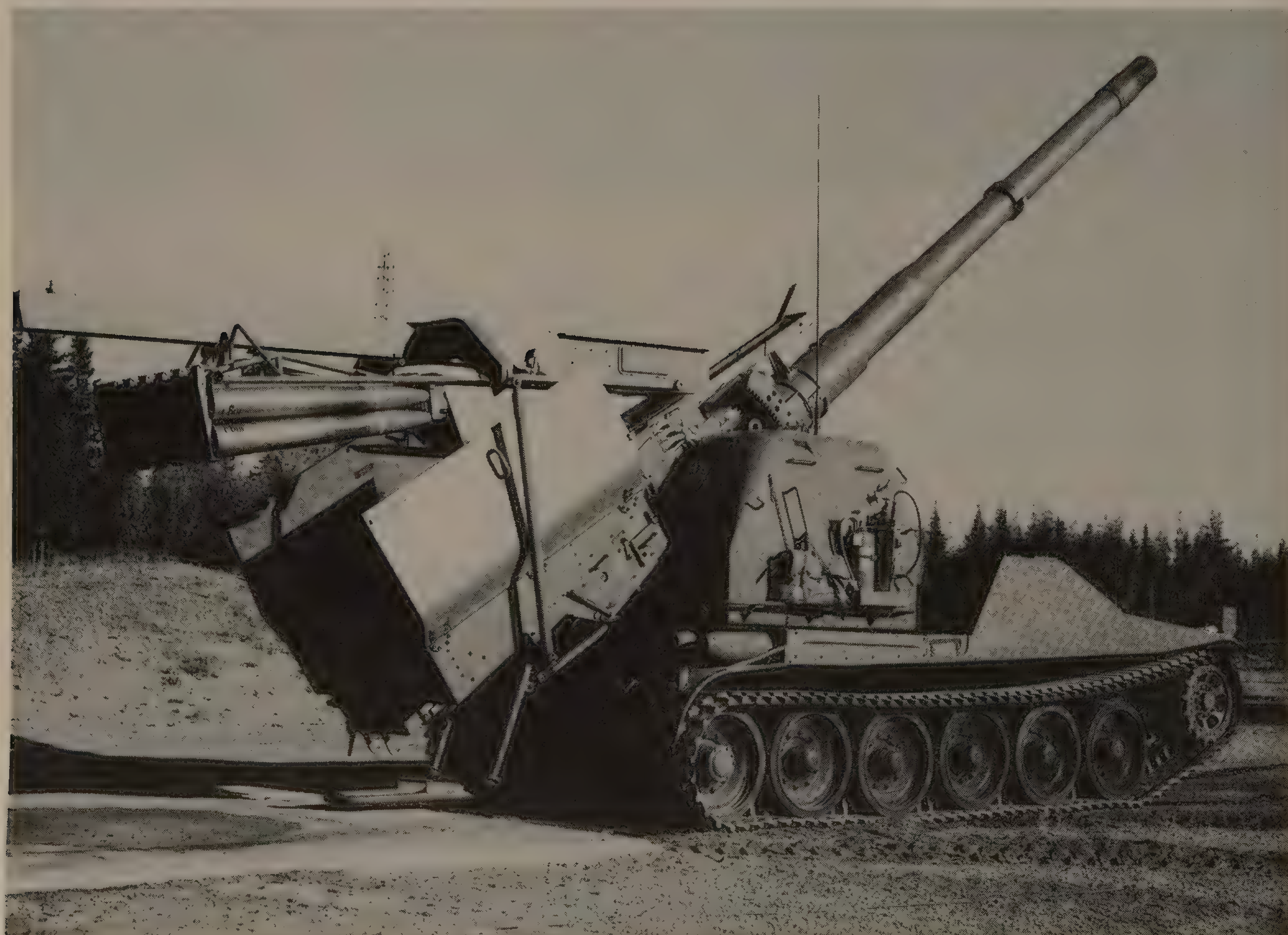
This loading system is the most complicated part of the whole design. The gun, unusually for this calibre, uses a fixed round of ammunition, the shell being carried in a metal cartridge case. A clip (there is no other appropriate word, even though it weighs close to a ton) of fourteen rounds is lifted from the supply vehicle by a hoist in the apparatus and placed in a magazine. Beneath the magazine is a loading tray running on rollers, and when the loading mechanism is set in motion this tray strips a round from the clip and transports its forward to the ramming position. From here the round is rammed into the breech by a spring rammer, the spring of which, like that of the loading tray, is cocked by the recoil movement of the gun. The vertical sliding block breech closes, the loading tray retracts and the gun fires. On run-out, the breech opens automatically and the spent case is ejected to the rear.

The magazine holds two rounds in each of seven compartments, is armoured, and is fed from the top through two armoured doors. All the loading apparatus is well-protected by armour, and the entire operation is carried out by remote control from inside the right-hand cabin, where the loader sits accompanied by an anti-aircraft machine-gunner. The left side is occupied by the gun commander, gunlayer and radio operator.

Strangely, with all this mechanization, the gun traverse and elevation are purely manual, though there is an auxiliary electric motor on the elevating gear which is intended solely to get the gun down from the firing angle to the loading angle (+2°). Once the magazine is empty the electric motor is used to run the gun up to 38° elevation, the armoured magazine doors are opened, and a fresh clip is hoisted up and loaded. The gun is then run down again to the loading angle; if this is the first round of the day, the loading tray has to be manually pushed to the loading position and the round manually rammed; after the first shot stored energy takes over.

All this complication leads to weight; the Bandkanon weighs 58 tonnes, almost twice as much as any current 15mm SP weapon, and has a top speed of only 28km/hr (17mph). It carries fourteen rounds on board and relies upon its supply vehicle to keep it topped up with clips. The 48kg shell has a muzzle velocity of 865m/sec and a maximum range of 25,600 metres. There are three propelling charges; but since the ammunition is fixed, once a clip is loaded, changing the charge is a complicated and slow business. It is, however, possible to fire all fourteen rounds in automatic mode which, without appearing to sound facetious, must make this the world's biggest machine-gun.

In the Bandkanon the Swedish Army had got what it ordered; whether it had got what it wanted is open to question. It seems as if it had not, for in 1966 the Army were back at Bofors' door asking for a towed howitzer with auxiliary propulsion. Whatever Bofors thought about the Bandkanon they kept to themselves and the towed gun they produced certainly showed that they were quite capable of good design when given the



chance. The resulting weapon was the FH-77 (later to become the FH-77A) and in 1975 the Swedish Army ordered 600 million Kronors' worth, followed by further orders in the early 1980s, bringing the total cost to SKr720 million. They currently have some 300 of the guns and simple arithmetic thus suggests that the FH-77 cost slightly more than the Bandkanon, though doubtless much of this is the result of inflation.

The FH-77 was actually the first of the 'modern' 155mm howitzers, with auxiliary propulsion, mechanized loading and various labour-saving devices; subsequent designs in this genre have owed a great deal to Bofors' original thinking. It is a two-wheeled split-trail equipment, the auxiliary propulsion cell being mounted ahead of the wheels, and with two retractable dolly wheels on the trail legs. The propulsion unit mounts a Volvo engine connected to two hydraulic pumps which drive hydraulic motors in the main wheels. Steering is achieved by varying the power to the main wheels, and the dolly wheels pivot freely and follow the direction of steering. They are also hydraulically powered to lift up and down so as to assist in unhooking from the towing vehicle, opening the trail legs and lowering them to the ground. The towing vehicle is usually a Saab-Scania 6 × 6 truck, and the gun's auxiliary propulsion unit can be powered up and engaged by the truck driver, using remote control, to give additional traction in difficult terrain.

The 38-calibre barrel is carried in a cradle and balanced by hydro-pneumatic presses, has a muzzle brake and a vertically sliding block breech mechanism. Elevation and traverse are performed by hydraulic power, as are ammunition hoisting and ramming. Hand pumps are provided to ensure hydraulic pressure

◀ Reloading the magazine of the 155mm Bandkanon with a clip of 155mm ammunition.

▶ The Bofors 155mm FH-77B at a test range. (Bofors AB)

◄
The Bofors FH-77 155mm howitzer being operated by three men. Note the powered ammunition arm lifting a fresh shell on to the loading mechanism.

►
Bofors FH-77B howitzers, for the Indian Army, under construction.

▼◄
Bofors FH-77B howitzer on tow; the APU can be operated remotely by the vehicle driver so as to obtain additional traction from the gun wheels.

should the auxiliary engine be out of action, and also for silent operation at night. There is a loading table and rammer; projectiles are hoisted inboard in packs of three and placed on the loading table, from where they are released one at a time to be rammed, the operation being controlled by the loader who is seated on the right of the gun. Another man loads cartridge cases on to the loading tray. The shell released from the loading table drops on to the tray, mates with the cartridge case and the entire round is rammed, the breech closing automatically behind the case.

The standard projectile is a 42.4kg HE shell which is fired at a velocity of 774m/sec to achieve a range of 22,000 metres with top charge. The cartridge case is of composite plastic and steel construction and contains the propelling charge in units which can be removed so as to vary the charge in six zones.

The Swedish Army embraced the FH-77, but the export market looked askance, largely because it was expensive and because it was tied to the peculiarly Swedish family of cased 155mm ammunition. Bofors quickly realized that, as it stood, the FH-77 had no chance of foreign sales, so they designed it into the FH-77B (which is why the original model became the FH-77A) specifically aimed at the export market.

The FH-77B differs from the -A model in four major points; the barrel is slightly longer, the breech mechanism is now an interrupted screw; the weapon is chambered to accept NATO-standard 155mm ammunition plus the M107 family, and there is a completely new hydraulic loading system.

The barrel is 39 calibres long, with a muzzle brake. The breech mechanism uses the Bofors screw mechanism, a unique design which uses a conical block with five threaded segments and which is considerably different from the Welin screw used by almost every other gunmaker. There is a percussion primer firing lock with automatic feed from a primer magazine. The loading system uses the same three-projectile loading table, but has a totally different ramming system since it now has to work with bagged charges. The loader releases a shell from the loading table on to the loading tray from the other side. The loading tray then swings the cartridge across to line up behind the shell, though well separated from it, and the head of the cartridge section of the tray now acts as a rammer and forces the shell into the chamber. With the shell securely located, the rammer retracts, taking the charge with it, but at

◀ The Bofors 155mm FH-77B at a test range. (Bofors AB)

▶ The Italian M56 105mm pack howitzer in standard form.

the entrance to the chamber the charge is stripped off and left behind as the rammer leaves the breech opening. The breech screw is then closed and a primer automatically loaded into the firing lock.

The FH-77B was carefully designed to be able to fire a variety of ammunition types. It will accept M107 family shells, NATO-standard FH-70 shells, ERFB shells and rocket-assisted projectiles; and it is anticipated that a base-bleed shell should be available very shortly. It is equally catholic about cartridges; any bagged or combustible charge currently in use will work in the FH-77B. The standard projectile is the Bofors HE M/77B which, with the maximum charge (Charge 9) has a muzzle velocity of 827m/sec and a maximum range of 24,000 metres.

The formula has proved successful; 48 guns were purchased by Nigeria, and in 1987 the Indian Government placed an order worth SKr25 billion (US$3.5 billion) for an undisclosed number of weapons, which some experts estimate could be as many as 1,500 over a ten-year period.

Italian Developments

Italy took its place on the world's artillery stage by virtue of a remarkably timely 105mm howitzer which was originally developed for the Italian Army and then went on to sell in large numbers all over the world; the last count indicated some 25,000 weapons sold to more than 25 countries.

The 105mm pack howitzer M56 went into production in 1957, just as NATO had settled on 105mm as being the close-support gun calibre. The weapon was designed around the familiar American 105mm semi-fixed round of ammunition, which was available world-wide, and, as a result, was immediately examined by a number of countries requiring a 105mm weapon and willing to contemplate one which used such a common round of ammunition. Among these countries was Britain, needing a 105mm weapon to fulfil its NATO commitment but faced with a delay of some years before its own designs could be perfected and put into production. The British Army adopted the M56 in 1958, where it remained in use until 1975 when replaced by the Light Gun and it is still used for reserve training.

The M56 is an ingenious design; as the pack howitzer designation suggests, it can be easily dismantled into eleven loads for animal transport or parachute dropping. One of the more innovative ideas is the mounting of the wheels on cranked stub axles so that they can be positioned high or low; in the high position, there is ample room for the howitzer to recoil at the highest elevation angles without striking the

◀ German mountain artillery with their modified M56 105mm howitzer; the shield is removed and a high-efficiency muzzle brake is fitted.

▶ The OTO-Melara 'Palmaria' 155mm self-propelled howitzer.

ground, while in the low position, used for direct anti-tank fire, the weapon has a low silhouette and good stability. The legs of the split trail are in three sections which can be folded up or removed; customarily, two sections are used in the field role, three in the anti-tank role.

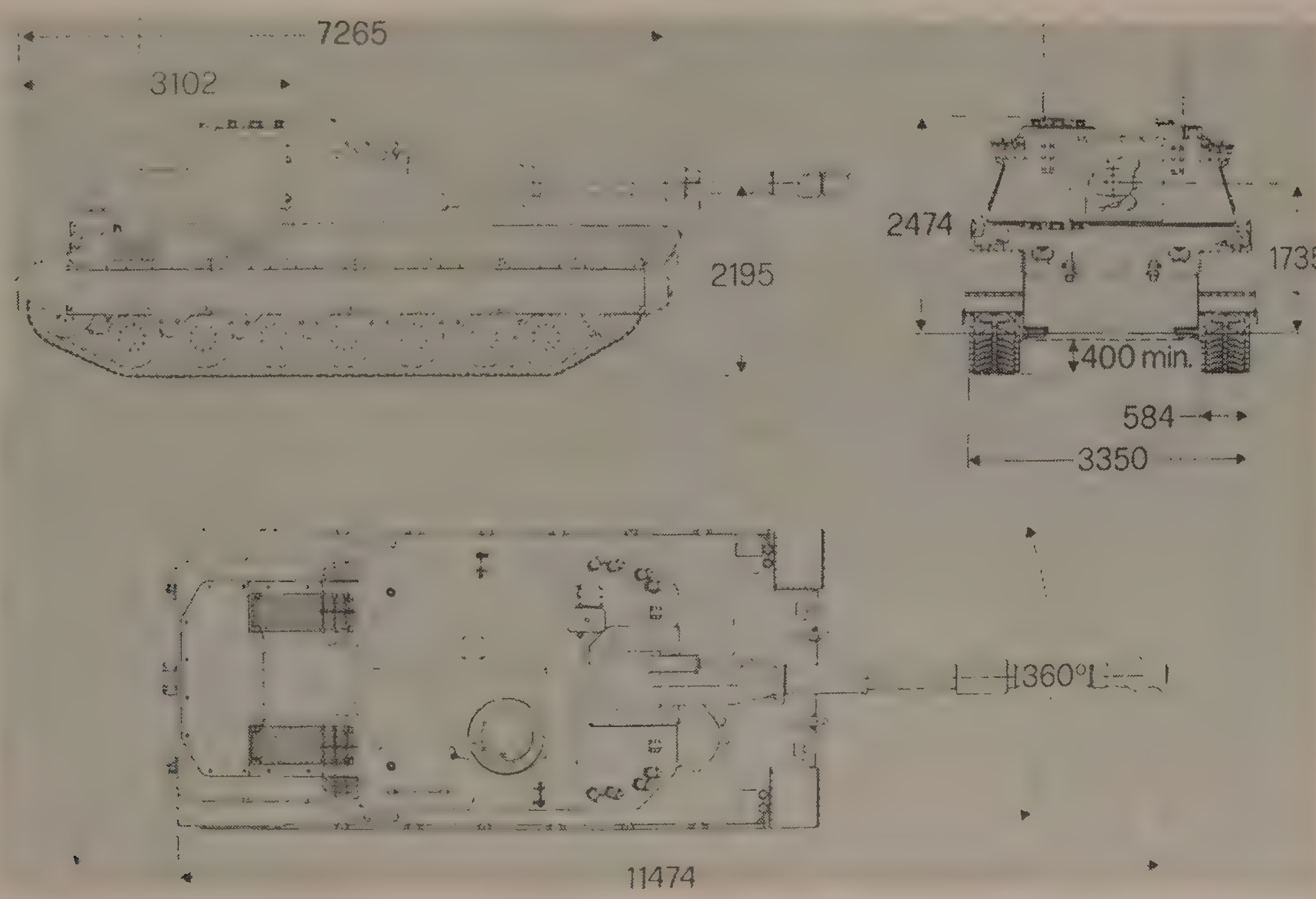
The ordnance is 14 calibres long and has a highly efficient muzzle brake and a vertical, rising, sliding breech-block. The gun is carried on a double recoil system, upper and lower, which allows the absorption of the recoil energy in a relatively short recoil stroke. The M56 fires the standard US 14.96kg shell to a maximum range of 10,575 metres; this compares with the 11,270 metres reached by the standard US M101 howitzer with the same ammunition, but the difference is that the M101 weighs 2,030kg while the M56 weighs only 1,290kg.

When it came to the 155mm calibre, the Italian Army was satisfied to operate entirely with American weapons, and continued to do so until the 155mm FH-70 was adopted. For SP equipment the US M109 family was adopted and continues to be used. It was left to a private company to develop a 155mm SP howitzer of Italian design, a weapon which was produced solely for export. The company was OTO-Melara, who made the M56 and have designed a number of highly effective and popular naval guns. The weapon was the 'Palmaria' self-propelled howitzer.

The 'Palmaria' began its development in 1977 and went into production in 1982, a commendably short interval. Time was undoubtedly saved by adapting the chassis and hull of the existing 0F-40 OTO-Malara main battle tank, though this has meant that the turret is centrally mounted, as in a tank, and the fighting compartment therefore somewhat confined in comparison with those 155mm SPs that have their guns mounted at the rear of the vehicle hull.

The ordnance is a 41-calibre barrel with muzzle brake and fume extractor, a sliding block ring-obturated breech mechanism and an automatic loading system. A magazine is located in the rear of the turret and consists of a linked row of tubes holding the shells. The

Dimensioned drawings of the Palmaria howitzer.



vehicle carries 30 projeciles, 23 of which are in the loading device, which can be fed from inside or outside the tank. When required, the selected projectile is transferred from the magazine into the loading tray, from which it is rammed into the breech with the gun at its loading angle of 2°. The propelling charge is manually loaded.

Ammunition for the Palmaria was developed by the Simmel company and consists of a standard HE shell, a 'Long Trajectory' shell in which the base drag has been drastically reduced, and a rocket-assisted projectile. All weight 43.5kg; the HE ranges to 24,000 metres, the HE 'LT' to 27,500 metres and the HE RAP to 30,000 metres. In addition smoke and illuminating projectiles have been developed.

The Santa Barbara Howitzer

Empresa Nacional Santa Barbara is the Spanish Government's gun development and manufacturing organization, and in 1973 they began development of a 155mm howitzer of their own design, the intention being to replace an ageing collection of 122mm and 155mm weapons of various origins. Although at that time Spain was not part of NATO there is no doubt that the designer looked ahead and developed a weapon which met all the relevant NATO specifications and would be capable of firing the standard NATO range of ammunition This policy was strengthened in 1977 when the Spanish Army adopted NATO standard for all future ammunition production, and in the same year

financial support for the howitzer project, which since its start had been negligible, was suddenly increased. The work was moved from the Cadiz factory where design had begun to a more modern factory at Seville, and a requirement for a self-propelled version was added. By 1982 a test gun had been built, with which to prove various components and also develop the ammunition system, and in 1984 the first prototype howitzer was built and tested. Since then, further prototypes have been built and the gun is now entering production for the Spanish Army in two forms, one with auxiliary power and one without, and the SP version is well on the way to acceptance for service.

The SB 155/39 howitzer is, as the title implies, a 39-calibre weapon. It has a muzzle brake and a semi-automatic vertical sliding breech mechanism with ring obturation. The ordnance slides in a trough cradle and is controlled by a hydro-pneumatic recoil system mounted above the barrel. The carriage is a two-wheel split-trail type, and the barrel is revolved above the trail legs and clamped there for travelling. Spades are formed on the trail ends, and there is a firing platform on to which the carriage is lowered by raising the wheels. In standard form the normal rate of fire is two rounds a minute, hand-loaded, though a rate of six rounds a minute can be achieved for limited periods.

The chamber is dimensioned so as to accept any type of 155mm calibre projectile; the standard projectile is a conventional HE shell, developed by Santa Barbara, which gives a maximum range of 24,000 metres, and

◄ The Santa Barbara 155mm howitzer on tow.

adoption of the US rocket-assisted shell should lift this to at least 30,000 metres.

The variant model of the SB 155/39 is the SB 155/39 REMA (Remolcado con motor auxiliar) which has an auxiliary power unit fitted in the usual position ahead of the main wheels, with retractable trail wheels for steering and trail-lifting. The engine is a turbocharged diesel driving an hydraulic pump to provide power to the main wheels and for the trail wheels and also to an hydraulic rammer.

An interesting and somewhat unusual spin-off from the 155/39 has been the proposal to bring the Spanish coast defence artillery up to date by removing the barrels from a large number of elderly Vickers-Armstrong 6in guns, built under licence in Spain from 1915 to 1925, and replacing them with the ordnance of the 155/39. This will enable modern ammunition to be fired to a range of 24,000 metres with minimum expense and conversion.

The self-propelled version is known as the SB 155/39 ATP (AuToPropulsada) and consists of the same 155/39 howitzer mounted in a turreted tracked vehicle. The turret is set to the rear of the hull, giving a moderately spacious fighting compartment with rear doors for ammunition resupply. The chassis uses torsion bar suspension and a GM V-12 turbo-charged diesel engine capable of moving the 38-tonne vehicle at 70km/hr on a good surface. The turret offers 360° traverse and the vehicle can carry 28 rounds of ammunition.

The Singapore Howitzer

This is the most recent addition to the 155mm howitzer crop, a 39-calibre gun-howitzer designated the FH-88. Development began in 1983, design was frozen in 1986 after the construction of five prototypes, and manufacture for service with the Singapore forces began early in 1989.

At first glance the FH-88 appears to be yet another auxiliary-propelled 155mm howitzer in the mould of the FH-70, FH-77 and GC-45 types, but on closer examination there are some ingenious differences. The designers of the FSH-88, the Ordnance Development & Engineering Company of Singapore, set out to develop a weapon with a better balance between power and

◄ The Spanish 155/39 REMA howitzer moving under its own power. (Santa Barbara)

manual operation than had so far been achieved in 155mm howitzer design, and they appear to have done this in a very satisfactory manner. The weapon, weighing 13.2 tonnes, can be emplaced in less than one minute by only three men.

The design of the carriage is the usual split trail, with four main wheels and an integral APU in front. The APU mounts a powerful 96hp Deutz turbo-charged diesel engine, which gives it a speed of 16km/hr on a good surface and the ability to climb a 45° slope. The APU can be brought into action by remote control from the cab of the towing vehicle so as to give additional traction in bad going, and – an unusual refinement – there is a hand-held remote control unit which allows the driver to stand well clear of the equipment and manoeuvre it in confined spaces, for example when loading it into a transport aircraft.

Hydraulic power is provided for assistance in bringing

▶ A recent introduction, the 155mm FH-88 howitzer from ODE of Singapore in the firing position.

the weapon into action. It is unhooked from its tractor by lowering the trail wheels to the ground and so lifting the trail end; opening of the trails is also assisted, after which the spades are dropped into place manually and the trails lowered to the ground. The APU then reverses the gun to dig the spades in and then lowers a firing platform beneath the front end of the trail. With this platform hydraulically placed, a mechanical lock linkage is added so as to relieve the hydraulics of firing shock, and the gun wheels are lifted from the ground; the balance of the walking beam suspension is such that the front pair of wheels rest on the ground while the rear pair are in the air, but no firing shock is passed to the suspension.

The gun is a 39-calibre ordnance with muzzle brake and a screw breech mechanism. This is semi-automatic in that it opens during run-out, but its closing is not automatic and must be done manually by one of the gunners. There is an hydraulically actuated flick rammer and an automatically loaded primer mechanism for the firing lock; NATO standard DM198 primers are used. The chamber and barrel contours permit the FH-88 to fire virtually any current type of 155mm projectiles; with the US M107 shell the maximum range is 19,000 metres; the NATO FH-70 M56 shell gives 24,000 metres, and a Singapore-designed ERFB shell offers 30,000 metres.

Finland and the Tampella Howitzers

The Tampella company came into the artillery business during the Second World War, developing a field howitzer and putting new barrels on captured Soviet carriages, though it is more commonly known for its many very good mortar designs. In the 1950s it was approached by the Finnish Army for a modern 122mm field gun, the result of which was the Model 60, which went into service in 1964 and is still in use.

For its period, it was a remarkably advanced design, with a 53-calibre barrel carried in a ring cradle, the recoil system cylinders being above and below. Trunnioned well to the rear, the long barrel is balanced by pull-type equilibrators, and the barrel has a muzzle brake and uses a semi-automatic horizontal sliding block breech. The carriage is a split-trail pattern with four wheels; two wheels, suspended on a walking beam, are attached to the forward end of each trail leg, so that as the trails are opened, so the wheels cant inwards, helping the work of opening. Altogether it resembles a smaller version of the American 155mm M1 gun except for the wheel action. For travelling the barrel is swung through 180° and clamped to the trail legs. Perhaps the most remarkable feature is an hydraulic motor system coupled to the gun wheels; this is connected to the towing vehicle, and the tractor driver can switch in hydraulic pressure to the gun in

order to drive the wheels and provide additional traction in difficult terrain. Once disconnected from the vehicle, though, there is no self-propulsive ability.

The Model 60 fires a 25kg shell at a maximum muzzle velocity of 950m/sec to achieve a range of 25,000 metres. It is used by the Finnish Army but has never been exported.

Tampella then began developing 155mm howitzers, but at that time the Finnish Army was not interested in that calibre, and the Finnish laws made export difficult, if not impossible. Tampella then, in some unclear manner, became involved with a nominally Israeli company called Soltam and the Tampella designs appeared in Israel under the Soltam banner (which also happened with mortars); they are described in the next section. It was not until the early 1970s that the Finnish Army began to look at the 155mm calibre with serious intent, whereupon Tampella drew on their earlier work to develop and build an entirely new weapon, the 155mm Gun-Howitzer M1974. Although this has been in existence for fifteen years, surprisingly little is known about it, since it was only put in service by the Finns in 1983 and is rarely on public view.

The M1974 uses a 39-calibre barrel and appears to be a progressive development from the Soltam M68 weapon (below). The ordnance has a muzzle brake and a horizontal sliding block breech and is carried in a ring cradle with the recoil system cylinders distributed above and below. There are pull-type equilibrators, and, altogether, the weapon is generally an overgrown 122mm M60 in general appearance. The carriage is a somewhat mysterious design; the manufacturers claim that the entire equipment can be put into action by two men, and there is a photograph showing one man opening the trail legs, with the gun wheels on his side off the ground. The weight of this equipment is 9,500kg, and one man lifting one side of that seems a trifle overdone; there must, obviously, be some sort of firing platform taking the weight, and some ingenious mechanical assistance somewhere in the system, but its details are not explained.

The M1974 fires a conventional 43.6kg shell at a maximum muzzle velocity of 850m/sec to reach a range of 24,000 metres. It is also understood that there is a base-bleed projectile which extends to a maximum of 30,000 metres. an unconfirmed report suggests that a 45-calibre barrel, with a corresponding improvement in range, has been developed for this weapon and may be retro-fitted to the originals in due course.

Israel and the Soltam Howitzers

As mentioned in the foregoing section, the Finnish Tampella company passed its early 155mm howitzer design research over to the Israeli company Soltam in the early 1960s, leaving Soltam to complete the development work and produce a weapon. The intention was to interest the Israeli Army, but at that time they appear to have had other interests and did not rise to the Soltam M68 gun/howitzer. Soltam therefore looked for export markets, and found some. Full details of their successful sales are not known, though the Thailand Royal Marines certainly deploy a number of these Soltam weapons.

The M68 gun/howitzer is very obviously from the Tampella stable, using the same type of four-wheeled split-trail mounting as used in the 122mm M60 gun. There is a firing jack under the front carriage, spades fitted to the trail legs, and pickets are driven in to anchor the trail ends. The ordnance is 33 calibres long and has a single-baffle muzzle brake and, most strangely, a fume extractor. There is little purpose in having a fume extractor on a weapon which has its breech end out in the open air, but Soltam were obviously looking ahead when they designed this weapon; it was to appear some years later as part of a self-propelled equipment. The breech mechanism is a semi-automatic sliding block with ring obturation for bag charges.

The M68 fires a 43.7kg shell at 725m/sec to achieve a maximum range of 21,000 metres. The design was completed sufficiently late in the 1960s to be able to adopt a chamber contour which allows any NATO projectile to be fired, as well as the universal American M107 family. In addition there was a special Tampella-designed HE shell which had its own nine-zone propelling charge system and could reach to 23,500 metres.

The response of the Israeli Army to the M68 is not known, but the Israeli respect for armour's manoeuvrability is well known and it seems highly likely that at that period they were more interested in a self-propelled equipment. At the time they were using a hybrid mating of the French 155mm Model 50 howitzer and the Sherman tank, the surgery applied to the tank being considerable. The best that could be said of it was that it worked, but it was hardly at the front edge of technology. Soltam therefore retired to their den and began working on what eventually appeared in 1973 as

the Soltam L/33. This, again, relied upon a redundant Sherman tank chassis for its mobility, but the design was rather more elegant than the earlier equipment.

The rebuild of the tank was quite extensive. The engine was replaced by a modern Cummins diesel and located beneath the floor of the gun compartment. The driver was placed at the left front, with the commander above and behind him, and the hull is built up into a slab-sided box with sloping front, from which the barrel of the howitzer appears. This crew compartment is completely covered, with cupola for an anti-aircraft machine-gun and a hatch for the vehicle commander, and there is a wide door in the rear for the crew to pass through and for supplying ammunition. In this application the point of the fume extractor becomes more obvious. The recoil system is variable, the recoil stroke shortening as the gun elevates, and there is a pneumatic rammer which allows loading at any angle up to the maximum elevation of 52°.

Performance of the self-propelled weapon is the same as that of the towed gun-howitzer. The vehicle carries 60 rounds of ammunition, of which sixteen are in ready-to-use configuration.

The success of the L/33, which was rapidly adopted by the Israeli Army, led to Soltam looking more closely at the possibilities of refurbishing elderly tanks by grafting modern artillery on to them, thus producing inexpensive (or, at least, *less* expensive) SP guns. In the early 1980s they announced their 155mm M72 howitzer which was a slightly changed L/33 howitzer in a newly designed armoured turret mounted into the hull of a Centurion tank. This showed no ballistic improvement over the L/33, but at least carried it on a more agile chassis and offered an attractive package for armies with ageing Centurions due for replacement in their primary role but still capable of several years of automotive service. Since then they have announced similar conversions to suit M48, M60 and Merkava tanks, though they do not seem to have had any takers.

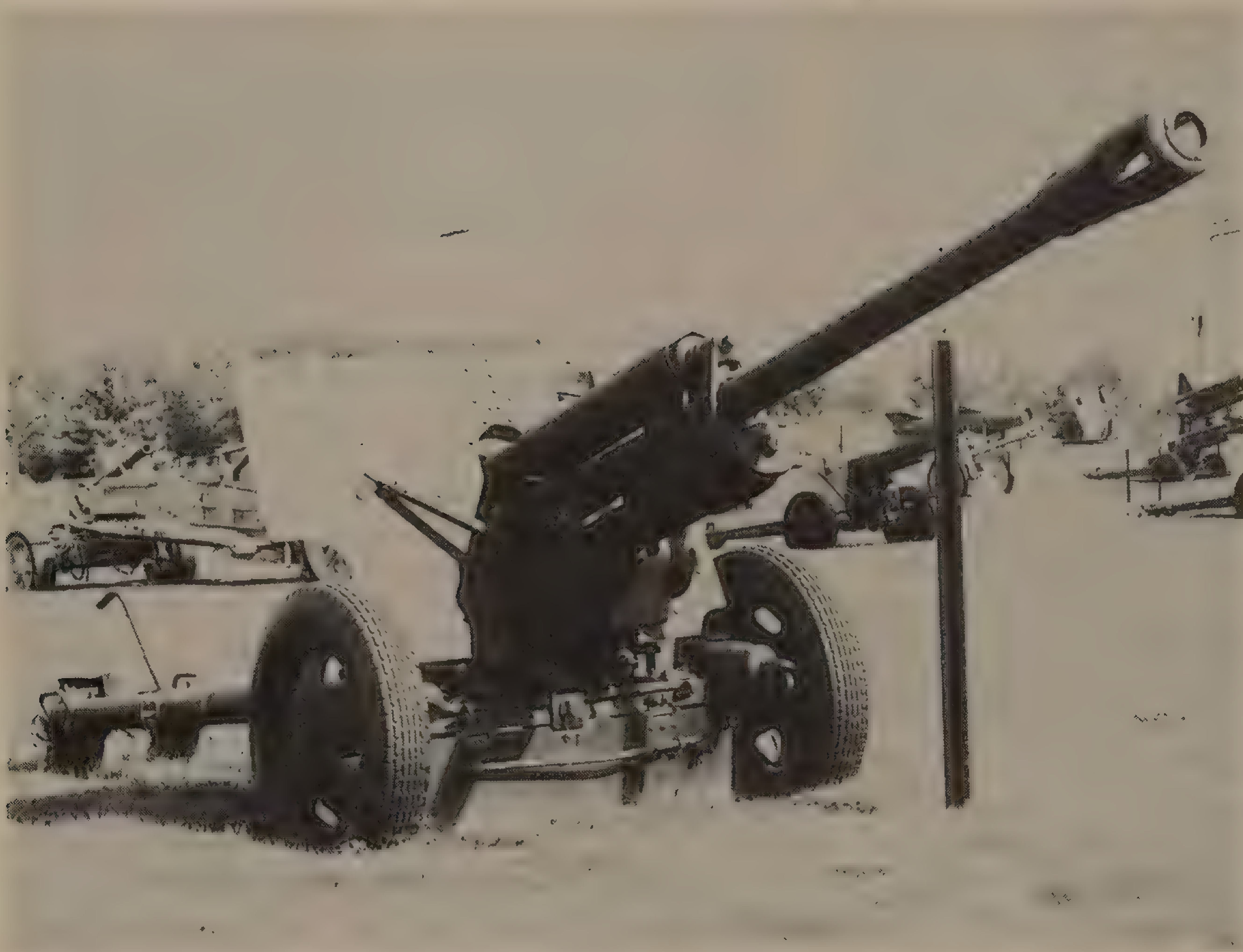
The Soviet Family

The Soviet Army, and Warsaw Pact armies generally, are renowned for their reluctance to throw anything away. Equipment which would have long ago gone to the scrapyard in Western nations is retained in reserve formations, in militia units, in war emergency stockpiles and supplied to fellow-travellers in all parts of the world. As a result there is a profusion of Soviet patterns of artillery which is added to by licence-produced copies, near-copies and derivatives. Some of these weapons date from the Second World War, some from even earlier, but they can all be found in use in various corners of the world.

One of the noticeable differences between Soviet and Western designs is the ratio between maximum range and equipment weight. In the West, looking at pre-1945 designs, this varies from 1.6:1 in the case of the US 155mm Gun M1, to 7.4:1 in the case of the British 25pdr gun. Soviet weapons run a far wider gamut, from 2.6:1 in the 122mm M1931/36 gun-howitzer to 11.3:1 in the 76mm Divisional Gun M1942. In general terms, Soviet weapons had longer range and weighed less than their Western equivalents. Western designers tended to sniff at this and make sharp remarks about the relative safety factors, implying that Soviet designers pared weight and pushed range at the cost of reliability; since we have no figures on Soviet gun endurance we cannot make any worthwhile comparisons, but bearing in mind the age of some of the guns still in use around the world, the reliability appears to have been satisfactory. Comparison of figures for more modern guns shows a general Western increase, from 2.65:1 in the case of the 155mm Howitzer FH-70 to 9.24:1 for the 105mm Light Gun, while the Soviets appear to have slid down to settle between 1.42:1 (180mm S23) and 4.73:1 (122mm Howitzer D30). So perhaps there was something in the safety factor theory after all, and the Soviets have improved theirs while the West, in turn, have relaxed a little. It is interesting to see that the most recent (post-GC-45) 155mm howitzer designs seem to run between 2.5 and 3.6 to 1, a figure which may be artificially lowered by the additional weight of the auxiliary propulsion systems. However, too much importance should not be attached to these figures, which merely indicate a tendency and do not adduce a rule.

Soviet 76mm Guns

The 76mm family is as old as the century, having been a favoured tsarist calibre, and there are still three weapons of this calibre in service; surprisingly, one was introduced just over twenty years ago.



◀ One of the most widely distributed guns in the world, the Soviet 76mm M1942 Divisional Gun, still to be found in smaller countries.

The 76mm Mountain Gun M1938 was originally a Czech design, developed by Skoda in 1936. In 1938 the Soviets took out a production licence and used it widely during the Second World War, afterwards retaining it in service until the late 1960s. It does not seem to have been widely exported, but it turned up in Afghanistan – in the hands of the Mujahadeen. It probably went there originally to arm elements of the Afghan Army and some were probably lost to the rebels, who put them to use. Like all mountain guns it is so designed as to be easily and quickly dismantled into various loads for mule- or man-carriage. It fires a 6.25kg shell to a maximum range of 10,100 metres.

The 76mm Divisional Gun M1942 is a light field piece with tubular split trail, designed with anti-tank performance well in mind. this caused it to have a limited maximum elevation, restricting the maximum range to 13,290 metres with the standard 6.2kg shell. Weighing only 1,116kg it is a light and handy gun, and has been widely exported to supply all the Warsaw Pact armies plus many African and Middle and Far Eastern countries. In Warsaw Pact armies it is a second-line reserve and training weapon, but elsewhere it is in full service and can be expected to turn up virtually anywhere where there is, or has been, Communist influence. It is obsolescent in every respect, but is still effective in sufficient numbers.

The most recent weapon of this group is the M1969 Mountain Gun, developed to replace the M1938 model. It fires the same ammunition as the Divisional Gun M1942 (instead of demanding unique ammunition as did the M1938, which simplifies supply) to a maximum range of 11,500 metres. Like the M1938 it can be dismantled for pack carriage, but weighs within a few kilograms of the earlier gun and, apart from a slightly better range and a standardized round of ammunition, shows little real advantage other than perhaps a more modern design. It has been seen in service in Afghanistan.

Soviet 85mm Guns

This calibre was developed during the Second World War to replace the 76mm Divisional guns (of which there were then several different patterns) but was not put into production until the war was over. The Divisional Gun D-44 was the first of the class and, as a

result of wartime experience, was designed with anti-armour performance well in mind. A long-barrelled weapon on a two-wheeled split-trail carriage, it fires a 9.6kg shell at 792m/sec to a maximum range of 15,650 metres. In the Soviet Army it is relegated to reserve and militia service, but elsewhere in the Warsaw Pact and in many African, Middle and Far Eastern armies it is in first-line service.

The D-44 was the first gun with auxiliary propulsion to go into service with any army. In the middle 1950s it was fitted with a 2-cylinder petrol engine on one trail leg, connected to the wheels by means of a propeller-shaft and differential. A trail wheel was fitted just behind the spades, and a steering wheel and seat for the driver were placed between the folded trail legs. With this, the gun could reach a speed of about 25km/hr over smooth terrain, and the modified weapon became known as the 85mm Divisional Gun Sd-44. It was issued to airborne units of the Soviet Army, thus relieving them of the necessity to take tractors with them in the first wave of airborne operations, but was abandoned in the 1970s after a restructuring of the Soviet airborne forces. It is still used by East German, Polish, Bulgarian and Cuban forces.

The Warsaw Pack armies are the only major armies to retain 'pure' anti-tank guns of conventional type – long-barrelled, high-velocity, limited-elevation weapons whose prime purpose in life is shooting at tanks, any other type of target being secondary. In other armies these have been entirely replaced by recoilless guns, rocket-launchers and guided missiles, but the Warsaw Pact armies are so large that even they baulk at the expense of sufficient missiles, so the old-style anti-tank gun still has a place. And, it might be said, given modern ammunition, they make a great deal of sense provided that the army that owns them has sufficient men to operate them; and manpower is a problem the WP forces don't have.

The smallest of these anti-tank guns still in use is the 57mm Model 1943, but its performance is negligible in the face of modern armour and it is no longer worth consideration. The smallest calibre worth its place on the battlefield is the 85mm D-48 gun; it was first seen in 1955 and assumed to be a 100mm weapon, but it was later found that it was of 85mm calibre, using the 100mm cartridge case necked-down to carry an 85mm projectile. It fires a hard-cored armour-piercing shot at about 1,200m /sec velocity, which enables it to defeat about 240mm of armour at 1,000 metres' range. With a maximum elevation of 35° it has a maximum range of 19,000 metres, firing a 9.7kg high-explosive shell in its secondary support role. It is in use in Soviet and Romanian reserve forces and has been exported to numerous African and Middle Eastern countries.

Soviet 100mm Guns

This calibre appeared in Soviet Army service in 1944, using a made-over naval gun placed on a two-wheeled split-trail field carriage. As with all the field guns of this era, it was designed with anti-tank performance in mind and has a long barrel and muzzle brake to extract all the velocity possible. It fires a 15.6kg high-explosive shell to a maximum range of 21,000 metres, and is also provided with both HEAT and kinetic energy anti-tank projectiles; the latter is a discarding sabot shot with a muzzle velocity of 1,415m/sec and the ability to defeat well over 250mm of armour at 1,000 metres' range. Replaced in Soviet service by the T-12 gun, it is still in wide use in African, Middle and Far Eastern armies and is still a useful weapon.

The 100mm Anti-Tank gun T-12 represents a far-reaching step in the development of this type of weapon, a step which has, so far, been ignored or resisted in Western armies. In brief, the technology that has been applied to tank guns over the past thirty or so years has been tapped for a field anti-tank gun, producing a weapon of considerable power. When the conventional anti-tank gun was abandoned in the West, it was largely because it had become far too big to be practical; the only really reliable method of killing a tank in 1945 was to fire a massive steel shot at it, and to provide a big enough shot with a powerful enough cartridge to do any damage demanded an enormous weapon. The armour-piercing discarding sabot shot had been developed by Britain and put into service in 1944, but it was still in its infancy and still demanded a heavy gun. The advent of recoilless guns and chemical-energy projectiles – shaped charge and squash-head shells – promised a lightweight weapon with sufficient power to deal with the contemporary tanks, and so, not without audible sighs of relief, the anti-tank gun was shelved. But the tank was still concerned with shooting other tanks, and its size and motive power meant that there was less restriction on the size of the gun, so that the ammunition and gun development which might have gone into the anti-tank

gun was diverted to the tank gun. This gave us smooth-bore guns, discarding sabot fin-stabilized 'long rod penetrators' and staggeringly high velocities – in tank guns.

Much of this development work had shown that these high-tech high-velocity projectiles would be effective in smaller calibres than had been considered feasible for old-style anti-tank guns. While there may have been ordnance engineers in the West who thought along these lines, there has never been much evidence that the idea was acceptable to armies. But the idea seems to have been given a hearing in Soviet Russia, and the T-12 gun was the result of it. It is a 100mm calibre smooth-bore gun firing fin-stabilized, discarding sabot, armour-piercing shot, based on the designs that had proved successful in the Soviet 115mm and 125mm guns. The projectile has a muzzle velocity of 1,500m/sec and will defeat 400mm of armour at 500 metres' range. The gun is also provided with a fin-stabilized HEAT (shaped charge) shell capable of defeating 400mm of armour at any range up to the gun's maximum effective anti-tank range of about 1,200 metres. It also has a 15kg HE shell which it can fire to 8,500 metres; this short range is due to the basic

▸ Image of power; the long-barrelled Soviet 100mm M44 gun.

anti-tank design, which means a maximum elevation of only 20°. The gun is used by Russia, East Germany, Hungary and Yugoslavia and may also have been sold to African countries.

Soviet 122mm Guns and Howitzers

The oldest member of this family is the Field Howitzer M1938 which, in spite of its age, is still in extensive use in the Warsaw Pact armies and in many countries round the world. It is a no-frills piece of 1930s technology, extremely robust and reliable and with a performance which is no more than average, but what it lacks in high technology it makes up for in the quantity in which it exists. The ordnance uses a Schneider-type screw breech-block with a brass cartridge case, and the carriage is a two-wheeled split-trail pattern with shield. It fires a 21.8kg HE shell at 515m/sec to reach a maximum range of 11,800 metres, and is also provided with the usual smoke, illuminating and HEAT alternative projectiles.

The 122mm Field Gun D-74 replaced another 1930s model in the early 1950s. It is a long-barrelled weapon on a two-wheeled split-trail carriage, and has the recoil system mounted above the breech and chamber, set an unusually long way back so that it helps to counterbalance the long barrel. The split trail carries a small wheel on each leg to help when unfolding, and there is also a firing jack which is lowered between the wheels to take the firing stress. It is a heavy weapon, and these aids and a nine-man detachment suggest that it might be difficult to deploy and operate. This gun, and the 130mm M46 (below) were developed independently to replace the earlier 122mm M31/37 gun; both were adopted, but after some practical experience the Warsaw Pact decided it preferred the 130mm weapon, and the D-74 was therefore exported to China, Cuba, Egypt, Peru, North Korea and Vietnam.

The 122mm Howitzer D-30 appeared in 1967 and replaced the older 122mm weapons such as the M1938 howitzer in the Warsaw pact armies. It has also been supplied to a considerable number of countries, including such unlikely ones as Peru and Finland. It is manufactured in Egypt, and the British Royal Ordnance Factory organization, under contract to Egypt, designed and built a self-propelled version using a British chassis, while the BMY Company of America produced another prototype on the M109 chassis, though there is no indication yet as to which the Egyptians will put into production. All this suggests that the 122mm D-30 is a popular weapon.

It has some affinities with a design developed by Skoda for the German Army in 1944, notably a three-legged trail which opens out like a letter Y and allows the entire top carriage to traverse a complete circle above it, the two wheels being lifted well clear of the ground. This makes it a very stable weapon capable of wide changes of azimuth with little effort. The weapon is towed by its muzzle, a towing eye being permanently attached, and on arriving in its position a small central

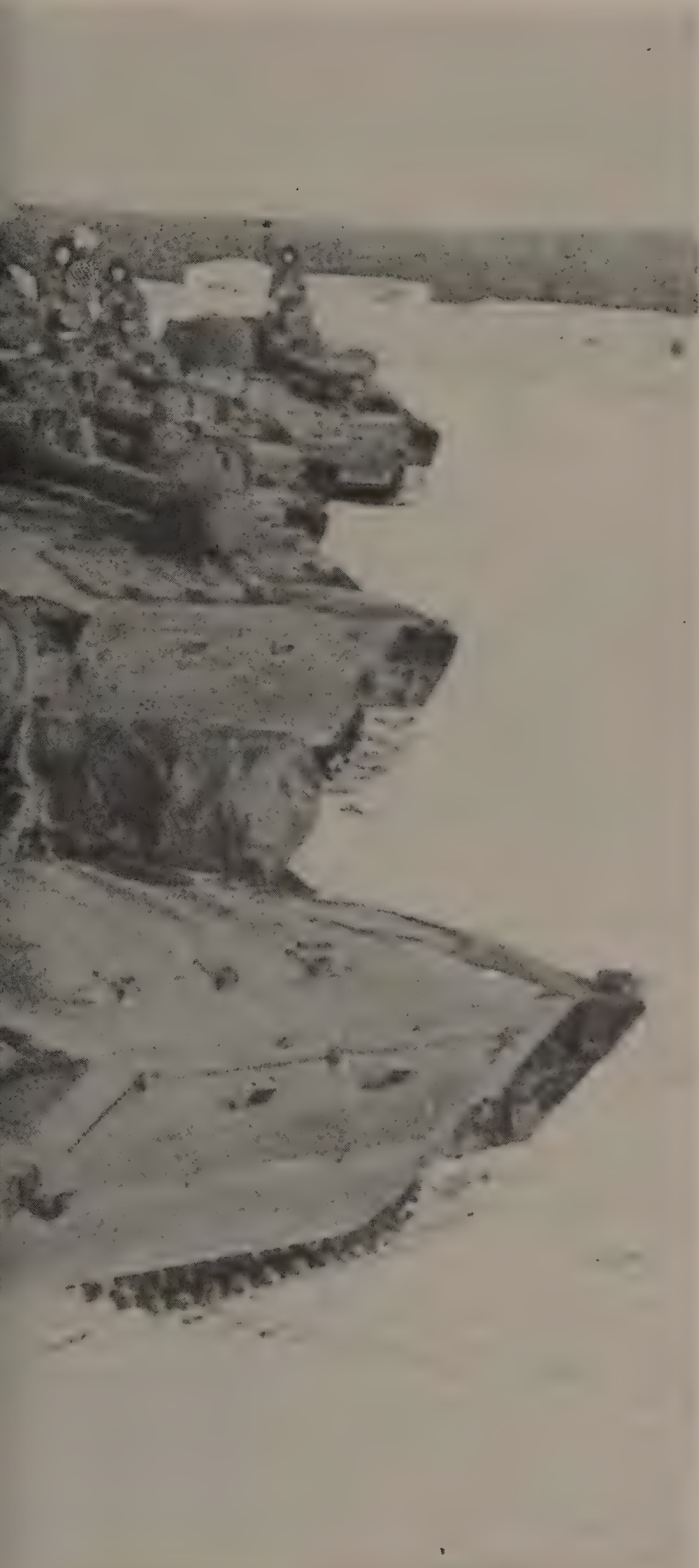
firing platform is lowered, the wheels lifted, and the three trail legs spread and staked to the ground. The breech is closed by a semi-automatic sliding block, the barrel is supported by a ring cradle, and the recoil system is above the barrel and protected by a steel shield. The standard projectile is a 21.3kg HE shell which is fired at 690m/sec to reach a maximum range of 15,300 metres. There is also a very efficient fin-stabilized HEAT anti-tank shell capable of penetrating 460mm of armour at 1,000 metres' range.

In May 1989 the Iraqi Government announced that the 122mm D-30 was now being manufactured in Iraq as the 'Saddam' gun. It is believed that the Yugoslavs were involved in the transfer of technology and assisted in setting up the manufacturing plant. The Saddam is somewhat heavier than the original Soviet weapon,

▼
Another common Soviet gift to developing nations is the 122mm howitzer M1938.

▶
The Soviet 122mm D-74 gun with firing platform folded beneath the cradle.

◀
A battery of Soviet 122mm D-30 howitzers, showing the three-legged platform and the towing eye folded under the muzzle brake.



and the Iraqis have also developed their own ammunition which gives the gun a maximum range of 17,100 metres. They also claim to have developed an Improved Conventional Munition projectile which carries a payload of anti-personnel bomblets.

The self-propelled 122mm equipment is the Howitzer M1974 (Gvozdika). This is a modified D-30 howitzer mounted in a turret on a special hull and chassis derived from the MTLB multi-purpose tracked vehicle. First seen in 1974, this weapon is widely used throughout the Warsaw Pact and has also been exported to African and Middle Eastern countries and to Yugoslavia.

The driver sits at the left front, with the engine to his right, and the fighting compartment in the rear of the hull supports the turret. This can be traversed through 360° and allows a maximum elevation of 70° to the howitzer. This has a muzzle brake, a fume extractor, and a semi-automatic vertical sliding block breech. A power rammer and cartridge case ejector are fitted, economizing on manpower and also allowing rapid loading at any angle of elevation. The vehicle carries 32 rounds of HE shell, six smoke shell and two HEAT/FS anti-tank projectiles. It has the same ballistic performance as the D-30, firing a 21.7kg shell to 15,400 metres or a rocket-assisted shell to 21,900 metres.

Soviet 130mm Guns

Immediately after the Second World War the Soviet Army demanded a really effective medium gun, with a better shell weight and range than the elderly 122mm M31/37 which had served throughout the war. In order to provide a quick solution, the existing Naval 130mm M1936 gun was taken as the ordnance, and placed upon a robust and simple split-trail carriage. The result was exactly what was wanted, though, as noted above, there had to be a period of comparative troop trials before the final decision to adopt the 130mm calibre was taken. Although called the M1946 it did not, in fact, make an appearance until 1954 and it was some years later before it began to enter service in numbers.

The barrel is very long – 7.6 metres including the muzzle brake – and is withdrawn in its cradle by a chain and gear system and clamped to the trail legs for travelling; this reduces the unsupported length of the

◀ The Soviet 122mm self-propelled howitzer M1974 (2S1), known as *Gvozdika* (carnation)

▶
The Soviet 130mm gun M46 comes in two versions; this is the 'modified' version, with a longer barrel, which appeared in the 1970s.

barrel and avoids excessive travelling stress over rough terrain. The recoil system is divided, above and below the barrel; the cylinders are attached to a yoke at the front of the trough cradle and are disconnected to permit the gun to be run back. For travelling, the trail ends can be supported on a two-wheeled limber or can be hooked directly to the towing vehicle. The gun has a pepper-pot muzzle brake and horizontal sliding breech-block, and fires a 33.4kg HE shell at 1,050m/sec to reach a maximum range of 27,150 metres.

Numbers of these guns have been captured by the Israeli Army in various battles, and they have changed the carriage to use a four-wheeled bogie in place of the normal two wheels. This appears to improve the suspension and balance of the equipment so that it is possible to tow it without having to retract the gun.

The only other 130mm equipment is a mobile coast defence gun, something of a rarity today. This uses a four-wheeled mounting similar to an anti-aircraft mount, with stabilizers which can be swung out and staked to the ground when the wheels are removed, allowing the gun a full 360° traverse. The ordnance is the Naval pattern, with a somewhat different barrel contour from the M-46 gun and a different muzzle brake. It also fires different ammunition, and the standard projectile is a 33.6kg armour-piercing HE shell which has a maximum range of 29,500 metres.

The Soviet 152mm Family

The calibre of 152mm has been a Russian standard since the Obuchov arsenal made the first breech-loaders in 1877, and there has never been a time when one or two specimens of this calibre have not been in service. The oldest weapon to be still serving is the Gun-Howitzer M1937, a quite conventional piece of 1930s design which shared the same solid-tyred two-

wheeled, split-trail carriage as the 122mm Gun M1931/37, distinguished by two spring equilibrators in front of the sloping shield. It fires a 43.5kg shell to a maximum range of 17,265m, and although no longer in service in the Soviet Army can still be found in some other Warsaw pact armies and in China, Cuba and Middle Eastern countries. Although still held in some numbers it is, in truth, obsolete, and need not be considered further.

Almost as old is the 152mm howitzer D-1, introduced in 1943. This, though, is rather more modern in its appearance and is still used throughout the Warsaw Pact, China and many other countries which have received Soviet aid. As a manufacturing shortcut this howitzer uses the same two-wheeled, split-trail carriage as the 122mm howitzer M-30, though it is strengthened and the recoil system also modified so as to accept the heavier loads. The tube is that of the earlier M1938 howitzer, but fitted with a muzzle brake to reduce the recoil load. The D-1 fires a 40kg shell to a maximum range of 12,400 metres, and although still in existence in large numbers is generally a reserve weapon in Warsaw Pact forces, having been replaced by the D-20 gun-howitzer.

The D-20 appeared in 1955, and in keeping with the usual partnering of guns and howitzers, uses the same carriage as the 122mm Gun D-74. This is a two-wheeled, split-trail carriage with a prominent firing pedestal which folds beneath the gun, in front of the shield. The barrel has a prominent muzzle brake and a vertical sliding block semi-automatic breech mechanism. The recoil system is above the barrel and projects ahead of the shield. There are two castor wheels on the trail, folded above it when not in use, which assist in opening the trail legs and, in conjunction with the firing pedestal, make it very easy to traverse through a full circle if necessary. The D-20 fires a 48kg shell at 655m/sec to reach a maximum range of 18,000 metres.

The self-propelled member of the family is the Gun/Howitzer SO-152 (Akatsiya). This uses a gun tube based upon that of the D-20 gun/howitzer, but fitted with a fume extractor and probably an automatic loading system. The vehicle is a modified version of the carrier first used with the SA-4 Ganef air defence missile-launcher and is easily recognized by the seven road-wheels with prominent gaps between the first, second and third wheels. The internal layout is similar to that of the 122mm SP M1974, with the driver at the left front, the engine on his right, and the rear of the hull taken up by the gun compartment and turret. The ballistic performance is the same as that of the D-20.

The SO-152 is widely distributed in the Soviet and East German Armies and has also been supplied to Iraq and Libya in some numbers.

The most recent member of the 152mm family is the M1976 field gun which, in spite of being now thirteen years old, is still something of a mystery; it was first seen in 1985 and very little hard information has reached the West. It is a long-barrelled gun with a muzzle brake, mounted upon a four-wheeled, split-trail carriage. It is known to fire to a maximum range of 27,000 metres with its standard HE projectile, and to 37,000 metres with a rocket-boosted projectile, but the weights and velocities are not known. It is also reputed to have a nuclear projectile.

As little is known of its self-propelled equivalent, the SP 2S5. This uses the hull and chassis of the 152mm SO-152 Akatsiya and has the gun mounted well to the

rear with no armour protection. A large bulldozer-type blade at the rear acts as a firing spade.

In general the Warsaw Pact armies use Soviet equipment, but the Czech Army has developed a unique self-propelled 152mm howitzer known as 'Dana', which uses a wheeled carriage. This was introduced in 1981 and is based on an eight-wheeled Tatra truck chassis which is fitted with an armoured body. The superstructure looks like a turret but is in fact two cabins (rather like those of the Swedish Bandkanon) with the howitzer mounted between them, all capable of revolving through 360°. There is an hydraulic crane above the mounting, which is used to hoist ammunition into the automatic loading system.

Although by now an obsolete design, there are still large numbers of the Soviet 152mm M1937 gun-howitzer in existence, particularly in 'Third World' armies.

Three stabilizers are mounted on the chassis, and these are lowered to the ground to stabilize the mounting before firing. Range is said to be about 20,000 metres with a 43.5kg shell. Apart from the South African G6 this is the only wheeled SP gun in service, and one would dearly love to know the arguments that persuaded the Czechs to choose this design. The Tatra chassis has remarkable cross-country ability in truck form, and it may well be that trials showed that it could perform as well as a tracked vehicle in the artillery role.

The 180mm S-23 Gun

The heaviest towed gun in Soviet service, this was first seen in 1955, and was originally thought to be of 203mm calibre; it was not until a number were captured from Syria by the Israelis that the true calibre was discovered. The gun is derived from a naval model and has a pepper-pot muzzle brake and a screw breech. The carriage is a two-twin-wheeled split-trail model using a two-wheeled limber to support the trail ends when being towed. The long barrel is drawn back in the ring cradle and clamped to the trails for travelling. In action a firing platform is lowered to the ground beneath the top carriage and the wheels are lifted clear.

The S-23 is rather unusual in Soviet service for firing a bag charge cartridge, and fires an 84kg shell at 790m/sec to a maximum range of 30,400 metres. It is believed to have a rocket-assisted shell which increases the maximum range to 43,800 metres, and also a 0.2 kiloton nuclear projectile.

The 180mm S-23 is used by the USSR alone in the Warsaw Pact, and has been supplied to Egypt, Syria and India.

The 203mm SP Gun M1975

This is the heaviest gun in Soviet service and has no towed equivalent. Issues to troops began in 1977 and it is now believed that some 500 have been deployed. Very little is known about it; no figures for weight of shell or range have been publicized, though some US agencies speak of 30,000 metres as the maximum range, which is probably an under-estimate. The chassis is a specially built one, resembling no other Soviet armoured vehicle, and has the driver and three or four crewmen in a cabin at the front, with the engine and transmission behind them. After this there are some stowage bins, which might contain ready-use ammunition, and the gun is mounted in the open at the rear of the hull. There appears to be a mechanized loading hoist, feed tray and rammer on the right rear, and the sights are on the left side of the breech.

Soviet Heavy Mortars

Mortars are generally considered to be infantry weapons, but, by strict definition, a mortar is any ordnance which fires *only* in the high angle bracket above 45° elevation. Their use outside the infantry or infantry support role is uncommon, but the Soviets have two heavy mortars which are big enough to qualify as artillery and are tactically handled as such.

The towed heavy mortar is the 240mm M-240, first seen in 1953. It is deployed with heavy artillery brigades of the Soviet Army at Front level and its purpose in life is the demolition of obstacles that cannot be easily dealt with by more conventional guns or howitzers.

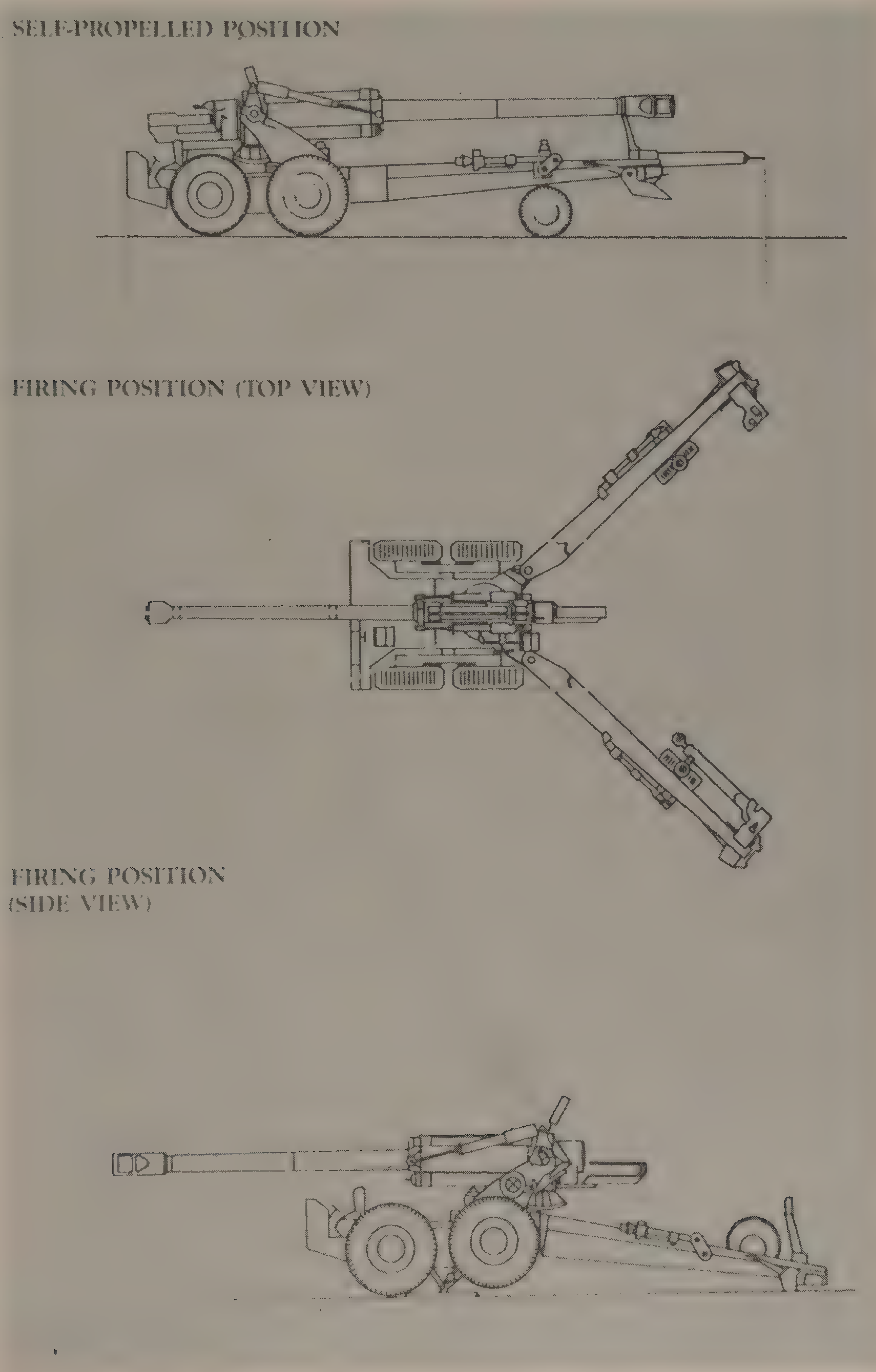
The M-240 is a conventional enough mortar in appearance, a large tube supported on a circular baseplate and an elevating framework carried on a two-wheeled axle. It is towed by its muzzle, with the baseplate at the rear, and drops easily into action. It is, however, breech-loaded, the barrel disconnecting from the breech-plug and being swung down so as to elevate the breech end. It fires a fin-stabilized bomb weighing 130kg to a maximum range of 9,700 metres.

The self-propelled version, the 240mm M1975, uses the chassis of the GMZ mine-laying vehicle and carries the mortar and baseplate on a cantilever arm hinged at the rear. When on the move, the barrel lies along the top of the vehicle. To go into action the barrel is lifted and hinged back on the arm so that the baseplate drops to the ground and the cantilever arm then supports the barrel and controls the elevation. The barrel is, in fact, entirely new and bears no relationship other than calibre to the towed M-240 version. It is believed to fire the same bomb but with a heavier propelling charge, giving a range of 12,700 metres, and it is also provided with a nuclear bomb, a chemical bomb and a special concrete-piercing bomb for dealing with fortifications.

The towed mortar is in service with the USSR and Egypt; the self-propelled version is used solely by the Soviet Army.

◀
On tow by AT-T heavy tractors, the 180mm Soviet S-23 gun.

▶
The Singapore FH-88 howitzer in firing and travelling modes.



Rockets

Colonel Boxer, Superintendent of the Royal Laboratory in Woolwich Arsenal in the 1860s, appears to have spent far too much of his time trying to make the primitive rockets of the period work with something approaching reliability, and he was once moved to observe that 'Had the rocket been invented first, what an improvement we would think the gun to be.' Artillerymen of my generation tend to the same view, having been exposed to some peculiar rockets in their time. But the missile industry, over the past forty years, has revolutionized the science of rocketry, and now that its experience has been applied to field support rockets, some reliable and accurate weapons have been the result. The free-flight rocket is now an accepted component of artillery, complementing the gun rather than replacing it, and some notes on the current state of affairs must be appended to our review of current tube artillery.

Rockets as bombardment weapons have been drifting in and out of military service for centuries, and Colonel Boxer's remark was fairly indicative of the general opinion on their utility. They died once more in the 1880s and were not seriously revived until the Second World War when the Russians and Germans pioneered their use, followed by the British and Americans. But whoever fired them, the opinion was the same; they were an 'area weapon', a slightly derogatory term meaning that they could not be relied upon to do

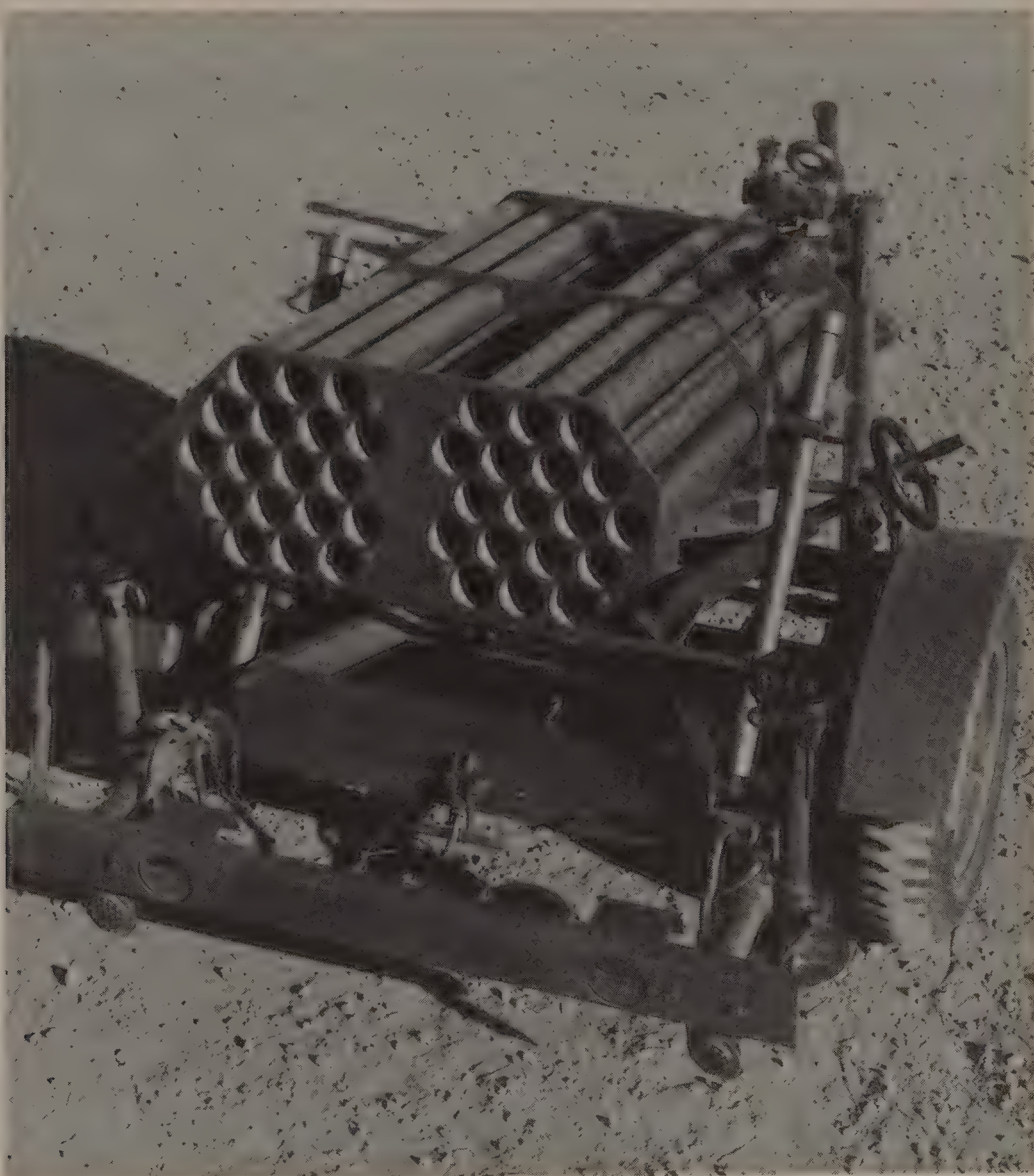
anything but blanket the general area of a target. This was generally due to three things: primitive propellant, cheap manufacture and rudimentary launching systems.

The missile era has taught us a great deal about propellants and the need for careful manufacture from good-quality materials. It has also taught us a great deal about assembly and design, aerodynamics and flight, all of which has brought about an enormous improvement in the ballistic regularity and accuracy of rockets. They are still unlikely to achieve the same degree of accuracy as a gun, but they are certainly far more accurate than their Second World War forebears.

Apart from a solitary obsolescent Japanese design, all present-day artillery rockets are classed as 'multiple rocket-launchers', insofar as they consist of a bank of tubes or rails on a vehicle or trailer, from which a volley of rockets can be fired. The firing circuitry permits the firing of single rockets, preselected groups of small numbers, or the entire contents of the bank of launchers. Volley firing – firing one rocket at a time, in succession, with a slight interval between, is the normal method, since salvo firing – all the rockets at once – generally leads to the blast interfering with the stability of the rockets and causes them to fly inaccu-

◄ Chinese 152mm Type 83 self-propelled howitzer.

► The Brazilian SBAT-70 36-tube rocket launcher. (Avibras)



rately. The rockets may be fin stabilized, or spin stabilized, depending upon the designer's ideas.

A good example of this group is the 110mm LARS (Light Artillery Rocket System) employed by the West German Army. It entered service in 1969, when other Western nations were still contemplating rockets, and it is still a very efficient system. It is carried on a 7-tonne tracked body and consists of a traversing launcher unit comprising two banks each of eighteen tubes. The launcher is elevated, traversed and aimed just like a gun. The standard rocket has a solid-fuel motor which burns for 2.2 seconds and has a minimum range of 6,000 metres and a maximum range of 14,000 metres. A high-performance rocket has a range of 25,000 metres. The warhead weighs 17.3kg and there are HE, fragmentation, smoke and sub-munition warheads available.

A weapon that fires 36 17kg warheads in eighteen seconds is obviously a formidable one, and the favourite claim of rocket enthusiasts is well borne out; that this is a weapon that delivers the same firepower as a medium artillery regiment but from one launcher. The other side of the coin is that it takes fifteen minutes to reload the launcher; it does not take fifteen minutes to reload a medium artillery regiment. Nevertheless, as a bombardment weapon, a group of these launchers can deliver overwhelming firepower.

However, in the 1980s the words 'Multiple Launch Rocket System' (MLRS) have come to mean but one thing; the American 227mm system which is in the process of being adopted by various NATO forces. While bearing a resemblance to the 110mm LARS and other systems insofar as it is a twin bank of rockets mounted upon a vehicle, the MLRS is a technological generation or more ahead.

Work began on a 'General Support Rocket System' in 1976, and in the following year two competing designs were approved for further development. In 1978 the project became directed towards a NATO-standard system, and Britain, France, West Germany and Italy came into the programme, the intention being that the launcher would be adopted in Europe and two production lines would be set up, one in the USA and one in Europe. The weapon now became MLRS, competitive trials between the two designs were carried out, and in May 1980 the Vought company was selected to produce the rocket and launcher. Various projects for ammunition were set up with companies in the USA and Europe. Issues to the US Army began in 1985, 41 batteries being planned, and by now almost all have been completed. The British Army intends to deploy three regiments and stated a requirement for 71 launchers. Four of these have been delivered from US manufacture, and are being used for training and evaluation; the remaining 69 are to be delivered from the European production, which appears to be lagging behind schedule. Germany wants 202 launchers, France 56, Italy 20, the Netherlands 30, and other NATO armies are contemplating adoption.

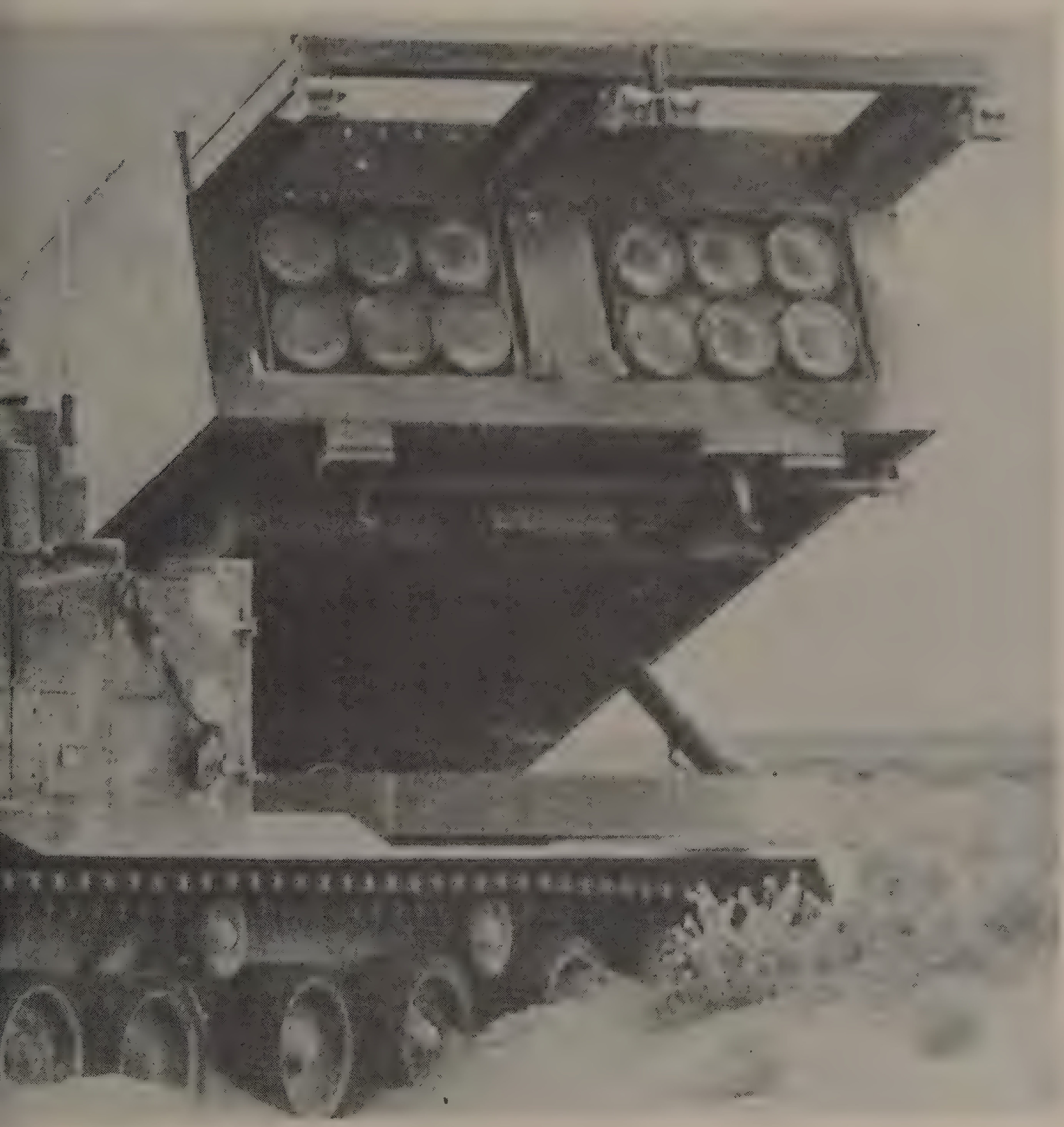
The launcher unit is a tracked vehicle based upon the chassis of the M2 Bradley Infantry Fighting Vehicle. It has an armoured cab at the front, and behind this is the launcher assembly. This is a large rectangular box,

capable of elevation and traverse, into which two six-rocket pods are loaded. Each pod is an aluminium cage containing six glass-fibre tubes, each having a rocket sealed inside. The launcher carries an hydraulic extendable boom which inserts the loaded pod and removes the empty tubes after firing, reloading a fresh pod. A resupply vehicle carries four loaded pods.

The rocket is 227mm diameter and 3.94 metres long, and is stabilized by folding fins which spring out after it leaves the pod. The rocket motor uses solid propellant. So far, this is conventional rocket design. But it is the warheads that make MLRS something different.

The M77 warhead weighs 154kg and it contains 644 dual-purpose shaped-charge/fragmentation bomblets capable of penetrating 100mm of armour. An electronic time-fuze in the nose opens the warhead at the selected point on the trajectory and thus releases the bomblets to fall to the ground beneath. With this warhead the maximum range is 32,000 metres.

West Germany had its own ideas on warheads and developed the AT2. This weighs 107kg and contains 28 scatterable anti-tank mines. The AT2 has a range of 40,000 metres and delivers the mines from an altitude of about 1,200 metres, so that a full volley of twelve rockets will deposit 336 mines over an area approximately 1,000 metres long by 400 metres wide. The mine carries a shaped-charge capable of piercing 140mm of armour.



◄ The Multiple Launch Rocket System (MLRS) ready to fire.

The US has since put other types of warhead into development, including the Tactical Missile System (TACMS) which uses an improved rocket to carry a submunition warhead to well over 150,000 metres' range, and a SADARM (Seek and Destroy Armour) warhead which deploys a number of parachute-stabilized warheads for the top attack of armoured vehicles.

The tactical operation of MLRS is the first service application of the autonomous principle. The vehicle is equipped with radio, inertial platform position determination, computer, and full automation. In effect, the commander is given a fire mission, including the location from which he will launch his rockets. He can set this location into the vehicle computer and position-finder, and then simply drive so as to reduce the differences on his computer to zero, which implies that he has reached the ordained site. He then feeds the computer with target data and meteor information. When it has worked out the data, the computer drives the launcher to the correct azimuth and elevation and fires the first rocket. The reaction causes the launcher to be displaced very slightly, the computer relays, and the next rocket is fired. This automatic operation continues until the desired number of rockets have been fired or the launcher is empty. The automated system then deploys the reloading apparatus and removes the empty pods, and, if the resupply vehicle is in place, reloads with two fresh pods. The whole equipment is operated by no more than three men, the driver, the commander and the gunner.

It can be easily appreciated that MLRS is a 'force multiplier' of considerable power. It is economic of manpower, easily dispersed and manoeuvred, and dispenses massive firepower. We can be sure that warheads of even greater ingenuity will be made available in the near future. It is understandable that the various NATO armies are anxious to equip themselves with such a weapon. The only cloud on the horizon is the near certainty that those armies will use MLRS to replace conventional guns, and not to reinforce them. No figures on the accuracy of the system have been released, but with a range of 40,000 metres it is unlikely to have the same accuracy as a gun at that range and it must, therefore, still be considered as an area weapon.

◀ The MLRS firing.

Having reviewed the artillery currently in or entering service, we must now turn to consider the designs that are presently undergoing development with a view to coming into service during the 1990s and which, the developers hope, will be the artillery of the year 2000. To be sure, we cannot hope to cover everything, since there must be several developments proceeding behind closed doors which have not been as much as hinted at publicly; and nobody can hope to forecast what might appear out of the Warsaw Pact countries or China in the next ten years. So we will confine our attention to those designs which have had some public discussion.

Britain

The principal artillery equipment question occupying the British Army at present is that of the replacement for the ill-fated SP-70 project. This, it will be recalled, was a tri-national project intended to use the FH-70 ordnance on a self-propelled mounting and thus, so far as the British were concerned, replace their existing 105mm Abbot equipment and possibly supplement the existing 155mm M109 regiments.

The Vickers Shipbuilding and Engineering Company appears to have had its private doubts about the viability of SP-70 some years ago, principally that whatever it would do for the three nations backing it, there would be little export potential in it since it would be far too expensive. In 1980, therefore, it began development of a gun and turret system which could be fitted into existing tank hulls so as to convert outgunned tanks to modern SP howitzers, extensive market research having indicated that there was a demand for such conversion.

The resulting GBT 155 turret appeared in 1982 and has since been progressively improved. The turret is of armoured steel, and mounts a 39-calibre gun with a new type of split breech-block developed by the Royal Armaments Research & Development Establishment (RARDE). This is a sliding block in two parts, front and rear; the front part carries a cylindrical chamber plug with pad obturation, while the rear part acts as a support. On closing the breech the two parts slide together until the plug is opposite the mouth of the chamber, at which point the rear part continues moving and thrusts the front part forward so that the plug enters the chamber and seals it. The rear part continues to move until it has firmly locked the chamber plug into place and thereafter forms a solid block between it and the breech ring. Thus the system gives the simplicity and compactness of operation of a sliding block breech, allied to the simplicity and security of pad obturation. The mechanism is semi-automatic and there is an automatic primer loading mechanism for the firing lock.

In the rear of the turret is a magazine holding 31 projectiles, with a simple transfer mechanism which moves the selected projectile to a central point whence

it can be manually withdrawn and placed on the loading tray. Above the shell magazine are containers for 21 propellant charges, with a further eleven charges at the front left of the turret. Additional ammunition can be stowed in the hull, the exact amount depending upon the type of hull adopted. There is a simple power rammer for the shell, the cartridge being manually loaded, and a burst of three rounds in thirteen seconds can be fired.

The turret is manned by four men: commander, layer and two loading numbers. Elevation and traverse is performed electrically, controlled by a joystick in front of the gunlayer; the commander has an overriding traverse control which he can use to direct the layer to a fresh target. Manual controls are provided for use in emergency.

An indirect fire sight is fixed to the turret roof and connected to the Gun Laying Computer (GLC). The sight sensors pass data of sight traverse, sight elevation and trunnion tilt to the GLC, while a sensor attached

◄ The Vickers GBT-155 turret and howitzer, mounted on a Centurion tank chassis; this design was intended to permit utilizing out-gunned tank chassis to form the basis of modern SP artillery.

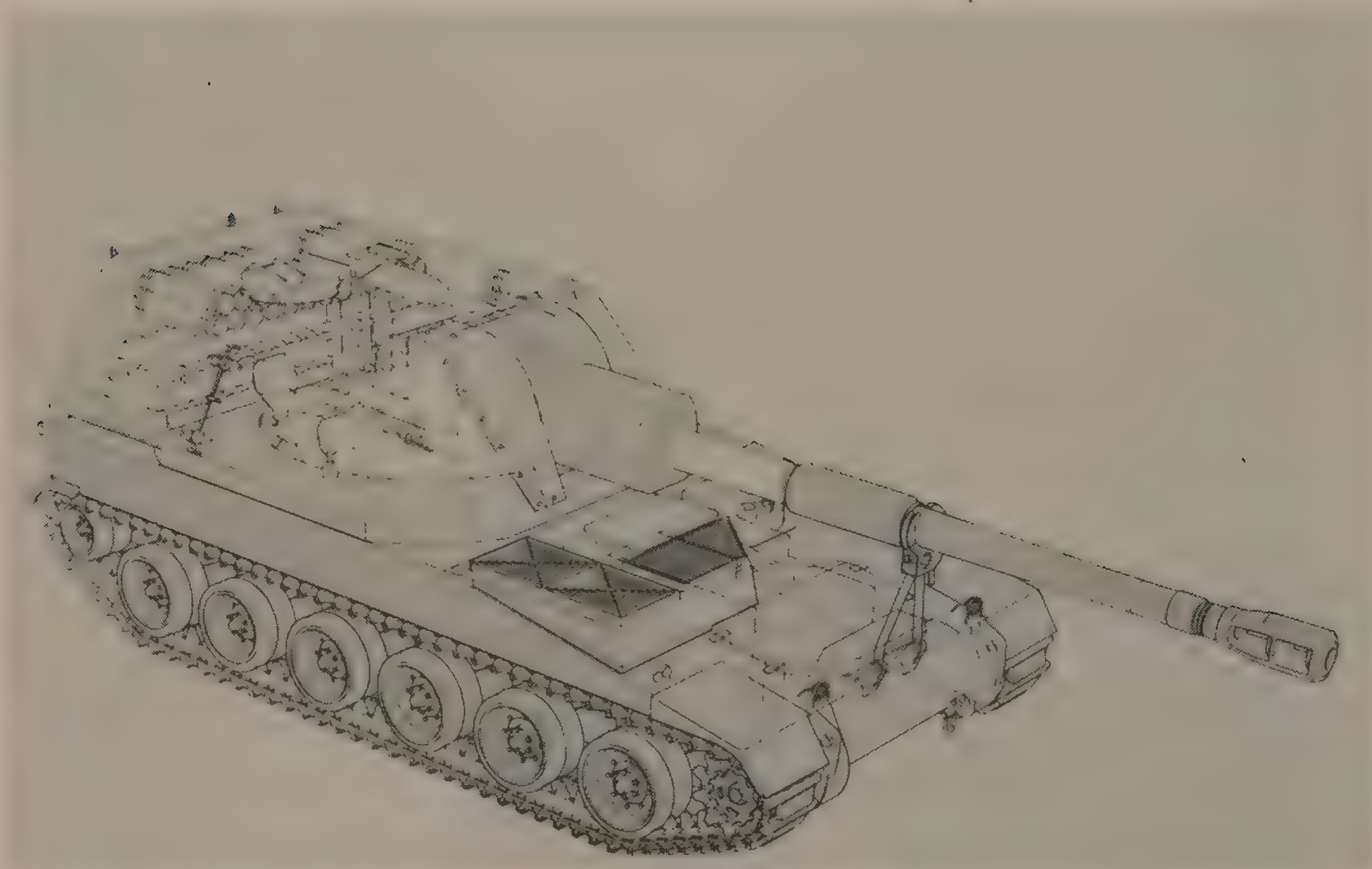
to the gun delivers gun elevation information. The GLC can be manually fed with map data (azimuth and range) and will then convert this to gun data (azimuth and elevation) relative to the chassis. The gun is then driven in traverse and elevation to bring it to this data; for elevation, the gun can be automatically driven by information from the GLC by the push of a button. The system is fully compatible with all standard gunnery and survey procedures.

Having developed the GBT 155 turret and tested it on a variety of tank chassis, Vickers then set about developing a complete equipment. Although the fitting of a howitzer turret unit to a tank chassis is attractive as a 'quick fix', it carries some drawbacks in its train. In the first place, a tank chassis is generally much too heavy for the task in hand, having been armoured and strengthened far beyond anything a self-propelled gun really needs. This means that the completed SP could well pose problems with bridges and roads in many countries. Moreover, the hull design of a tank is not well adapted to a howitzer, since it confines the turret and detachment to a relatively small space in the middle of the hull, and there is little space available for the carriage of ammunition. These and other considerations led Vickers to the design of a purpose-built hull and chassis properly matched to the turret and howitzer. It also led them to redesign the GBT 155 turret; this had been specifically designed with tank mounting in view, and therefore the diameter of the turret ring was chosen to fit existing tanks. With this restriction removed, the turret ring could be made larger and thus allow the detachment more room to operate.

At the time of these thoughts the principal market for the final equipment was discerned as being abroad, and therefore Vickers set about forming a consortium to handle the complete project. Vickers would deal with the turret and howitzer, the Cummings Engine Company of the USA would produce the engine and transmission, and Verolme Estalieros Unidos of Brazil would develop the hull. The prototype was built in the Vickers factory and first shown in 1986.

The design is aimed at a simple, easily maintained and operated weapon capable of the same performance as the FH-70 towed howitzer and with ample scope for future development. Improvements on the original turret have been made, and the magazine now contains 29 projectiles with a further eleven stowed elsewhere. Minor improvements have been made to the loading

◄ The first showing of the Vickers AS-90 howitzer, at the British Army Equipment Exhibition 1988.



Phantom drawing of the Vickers AS-90 155mm howitzer, now under construction for the British Army.

system and three rounds can now be fired in ten seconds. Automatic laying for both traverse and elevation is now standard, and provision has been made for adding a laser ring gyroscope inertial platform for position information, giving the weapon total autonomy.

This new design became 'AS 90' (Artillery System of the '90s), and when the SP-70 project finally collapsed, the British Army was faced with three alternatives; it could take more of the M109A2 equipments from the USA; it could adopt the AS 90; or it could start all over again to try to develop a completely new SP howitzer.

The latter course was obviously out of the question; after the waste of money due to SP-70, Parliament was unlikely to look favourably on another open-ended project. The first course had financial attractions, but, in the last analysis, was simply perpetuating a thirty-year old design, albeit periodically upgraded. The only course which made sense at all was to back the AS 90 project, since this promised a simple, practical and effective equipment with ample scope for future development. Sense or not, the deliberations were long and anguished, and it was not until June 1989 that the decision was finally taken to place an order with Vickers for 179 AS 90 equipments, plus spares, for a total price of £300 million, with an option of ordering another 50 equipments within the next five years.

AS 90 will fire the current FH-70 ammunition with a maximum range of 24,700 metres with standard projectiles and 32,000 metres with ERFB shells. What it will reach with ERFB-BB or rocket assistance has not been disclosed, but it would seem likely that 40,000 metres is well within reach. The design of the turret will allow for the future fitting of 45-, 47- or even 52-calibre ordnance with very little modification, and there is sufficient room in the turret for fully automated loading systems or improved fire control systems as and when they might appear.

The 179 equipments will replace four regiments of 105mm Abbot and two regiments of the oldest M109 equipments in the British Army of the Rhine. Each AS 90 regiment will have 24 weapons in three 8-gun batteries; this accounts for 144 weapons and the remainder will be used for training and reserves. Should the additional option be taken up, the remaining two M109 regiments in BAOR will be re-equipped. It is forecast that the first AS 90 regiment will be operational in early 1992.

Germany

The West German Army had a total requirement for 1,254 new SP 155mm howitzers which, it was hoped, SP-70 would fill. Their options were much the same as those available to Britain; buy M109A2s, upgrade existing M109A2s, or design something new. The initial

One of the proposed designs for the Federal German Army 155mm Panzerhaubitze 2000.

reaction was to procure 80 M109A2s from the USA, though this was later cancelled. The 'interim' solution adopted is to upgrade 586 existing M109A2 equipments into M109A3G versions, which means replacing the existing barrels with new 39-calibre barrels which will allow a standard range of 24,000 metres and an extended range of 30,000 metres. This upgrade was developed by the Rheinmettal company some years ago and was broadly approved for some time in the future, but the collapse of the SP-70 accelerated the programme.

For the long term, in December 1987 contracts were awarded to the Wegmann and Krauss-Maffei companies for development of the Panzerhaubitze 2000, a totally new equipment. By late 1990 the two companies will be expected to produce fully equipped and tested demonstration equipments for Army trials. Competitive trials will then be carried out and a choice made, based upon both technical and economic criteria. All the technical information garnered as a result of the SP-70 programme will be available to the two companies, and there is a possibility that Italy may enter the programme. Mock-ups have been produced by both companies, which show that the hull will have the engine at the front and the turret at the rear, so giving more room for the detachment and the auto-loading mechanism. Originally a 39-calibre howitzer was envisaged, but recent information indicates that a 52-calibre barrel has now been adopted. It is also reported that Germany is showing interest in the British As 90 programme, and should this meet their requirements it is possible that the expensive PzHb 2000 project will be terminated.

The United States of America

The past ten years have seen proposals for artillery improvement come and go in the USA with a rapidity that leaves the observer gasping. No sooner had he absorbed ESPAWS (Enhanced Self-Propelled Artillery Weapons System) than it was gone and he was invited to contemplate the joys of AFAS (Advanced Field Artillery System), HIP (Howitzer Improvement Program) HELP (Howitzer Extended Life Program), DSWS (Divisional Support Weapon System), MAS (Modified Armament System) and another dozen like them which shuttled in and out of focus at great speed. Most of the proposals put up in this time have been abandoned due to their excessive cost, and the present programme, a more modest one than many of its predecessors, is HIP.

The HIP programme is a joint venture between the USA and Israel to upgrade the various models of the M109 self-propelled 155mm howitzer to make them suitable for operations at the turn of the century. The programme is more or less based upon earlier studies carried out in the USA in the late 1970s, such as

ESPAWS and DSWS, programmes aimed at developing an entirely new family of artillery. Financial and technical problems arose with these programmes, and they were eventually shelved in favour of HELP, which aimed at improving the existing M109 weapons. HELP then gradually turned into HIP, for which a development contract was awarded in late 1985.

In 1983 the US Army issued a 'Mission Element Need Statement', a somewhat cumbrous expression for what amounted to a piece of paper saying what they didn't like about the current weapons and what they wanted to see by way of improvement. Like most of this class of document it was replete with broad statements and sweeping demands for improved RAM (Reliability, Availability, Maintainability), faster response time, greater terminal effect and improved survivability, without going into too much detail about how it expected these things to be achieved. But this document has been the guideline for the HIP designers, with the added proviso of tight financial and physical limits; the cost of improving an existing equipment, a figure which includes all the overhead charges such as development costs, changes in workshops and depots and so forth, is not to exceed $500,000, and the final design of howitzer must not exceed 27,200kg in weight.

The first area addressed was that of survivability. A US Army study made in 1984 suggested that dispersing guns more widely, instead of concentrating them within a closely defined battery area, would allow them to evade counter-battery bombardment and thus survive in battle for far longer. By providing each weapon with fire-control equipment which would allow it to operate semi-autonomously the battery could be widely dispersed with as much as one kilometre between each weapon. Supporting vehicles – ammunition carriers and command post – could be similarly dispersed, ensuring that the standard form of counter-battery fire would be incapable of damaging more than one or two equipments, and that to ensure the entire battery was neutralized would demand an excessive increase in the amount of counter-fire deployed. Analysis showed that, given widely dispersed eight-gun batteries instead of concentrated six-gun batteries, a divisional artillery would have three times as many operational weapons after the first five days of combat.

Survivability also means ensuring that the individual howitzers and vehicles have the ability to move rapidly when attack is imminent, and ensuring that the equipment provides a reasonable degree of protection for the detachment in the event of their suffering a sudden attack before they can move.

The M109, like many other vehicles of its generation, uses aluminium armour which is adequate against small-arms fire and small fragments. Against some of the more advanced methods of attack currently being deployed, such as bomblets from artillery-delivered munitions, the protection is marginal, and lining the roof and sides of the gun compartment with Kevlar woven armour fabric will defeat much of the spalling and direct penetration likely to occur. Relocating the hydraulic reservoirs and pipelines will also reduce the hazard of fire within the gun compartment.

Unlike a tank, self-propelled howitzers like the M109 cannot be sealed to give complete protection against chemical attack, and therefore the detachment must wear NBC suits when the threat arises. In the proposed HIP design, an air-conditioning unit with chemical filtration is to be fitted into the roof of the gun compartment. This will provide cool, filtered air which will be piped to the individual members of the crew who will wear ventilated face-masks and cooling jackets beneath their NBC suits.

Survivability is also the reason behind the incorporation of a fire-extinguishing system and the relocation of the ammunition storage. All projectiles are to be stored beneath the turret ring in the chassis, and the turret bustle containing the propellant charges, will have armoured shutters and exterior blow-out panels so that any explosion within will be kept from the gun compartment, and the flames will be vented to the exterior.

Response time to fire missions, and the ability to operate widely separated from other howitzers and the command post, will be aided by the Automatic Fire Control System (AFCS). At the heart of this lies a ring laser gyro Modular Azimuth Positioning System (MAPS) which can function as a stand-alone inertial system or as an odometer-assisted system. It will be able to determine the howitzer's location to an accuracy of 10 metres in plan and altitude, and a given heading accuracy of between half and one mil (between 9 and 18 minutes of arc). MAPS will feed the AFCS with the howitzer's position and heading; target data, either from a fire direction centre or direct from a forward observer is fed in, together with meteor and other ballistic data, and a computer then calculates the appropriate azimuth, elevation and charge and automatically lays the howitzer on that data. All that

remains to be done is to ensure the gun is loaded and give the order to fire. An interesting innovation is the inclusion of 'training software' in the system, allowing gun detachments to practise various fire control and gunnery techniques without requiring outside assistance.

The RAM (reliability, etc.) requirement is met by the incorporation of electronic test and diagnostic equipment, rather similar to some of the engine diagnostic devices seen on modern cars. This allows the crew to perform tests on the various electronic and mechanical systems and will identify faulty components and, in some cases, indicate incipient failure. This means that repair crews can be called for and given some idea of what the fault is, so that they can come with the proper tools and spare parts.

Other useful improvements include a system for disconnecting the transmission from the tracks, so that the howitzer can be more easily towed in the event of mechanical failure, and an external power input so that the ammunition vehicle can be connected as a source of electrical power in an emergency.

All this, of course, is merely the underpinnings of the howitzer itself; equally, much of it would be wasted by putting an obsolescent piece of ordnance into the vehicle. So the choice of the actual ordnance is critical, and here we enter a rather involved area.

Looking first at the broad picture, the adoption of any 155mm howitzer by a NATO army is bound up with a Quadrilateral Ballistics Agreement made several years ago which lays down certain characteristics that must apply so that inter-operability of ammunition can be assured. The key feature of this is the relationship between chamber volume and calibre-length, since this governs the muzzle velocity to be obtained from various charge systems, the chamber pressures, and the acceleration of the projectile. Without this agreement the NATO armies would be harassed by innumerable 'ifs' and 'buts' about what shell could be fired with which charge in what howitzer. The current standard weapons, the FH-70 and M198 howitzers for example, use a 39-calibre barrel and a chamber capacity of 18.8 litres. Howitzers that do not adhere to this standard – the GC-45 is one – can deliver very good performance with their own unique projectiles and charge systems, but fall short of the standard performance when firing NATO standard charges and shells.

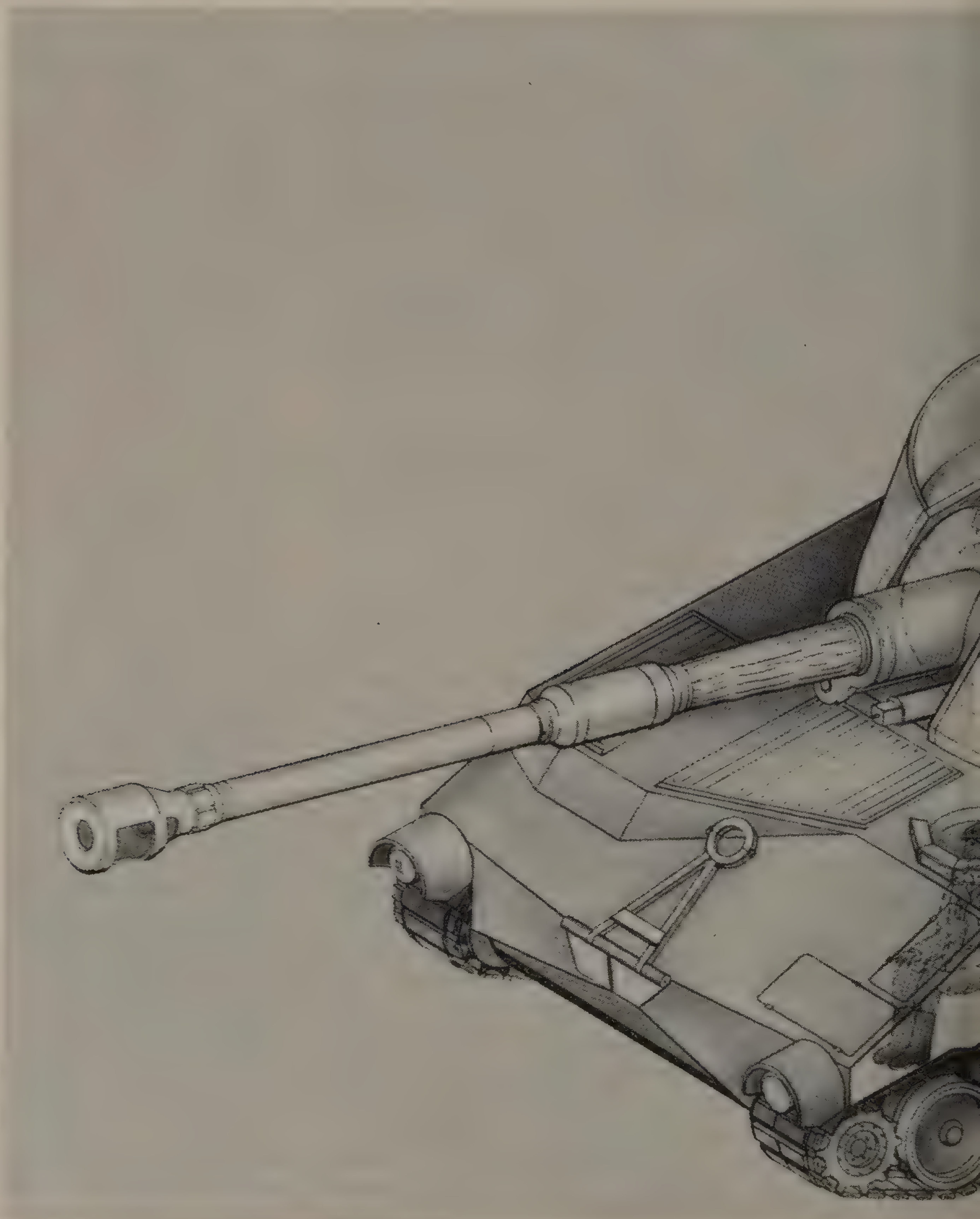
The first choice for HIP, therefore, and that ordnance which is generally assumed will be fitted to the first to be produced (assuming the project to be adopted) will be the XM284 Modified Armament System. This is simply the existing M109A2 ordnance with a strengthened torque key to prevent it twisting in the cradle under the forces generated by a new maximum charge. Adoption of this new Zone 8S will allow a range of about 29,000 metres to be reached with a base-bleed projectile, and 30,000 metres with a rocket-assisted projectile. But it will not permit an increase in range with the existing Improved Conventional Munitions, since the acceleration and pressure generated by the Zone 8S exceeds their design limits.

The next forecast step would be to adopt the 'Advanced Armament System', which involves a completely new mounting as well as new ordnance. The XM283 howitzer will be another 39-calibre model, so no ballistic change can be looked for in that direction, but the mounting would incorporate semi-automatic loading, a dual recoil and recuperator system to spread the load and reduce the likelihood of failure, a built-in test system and a built-in cooling system. Alternatively, the same improved mounting could be used to carry a completely new howitzer, the XM282. This is a 58-calibre weapon with a chamber volume of 27.9 litres which, with a new top charge, would be able to send a base-bleed shell to 45,000 metres' range. At the same time it would still be able to fire the existing US Army 155mm howitzer shells and charges. There is some doubt about this weapon, though, since the chamber volume-calibre length ratio falls outside the Quadrilateral guidelines. Moreover the 58-calibre howitzer is considerably different in dimensions – 9m long instead of 6.1m and 2,880kg instead of 2,000kg – which means an added load on the vehicle and problems with balancing. It has also been put forward that the additional recoil stroke necessary to soak up the extra energy would restrict the maximum elevation and thus the minimum range, making the weapon excellent for long-range bombardment but incapable of close support. Both the new howitzers are to be designed so that the ordnance can be removed and replaced within one hour (doubtless given the appropriate lifting machinery) and thus it has been suggested that both barrels should be made available and changed to suit the particular weapon's current tactical role. If it is possible to predict a howitzer's likely targets well in advance this idea might be feasible, but it does not sound a very practical idea to be exercised in real war. a more sensible suggestion is that these 58-calibre

weapons might well be used to replace the existing 203mm howitzers whose normal employment does not envisage close support.

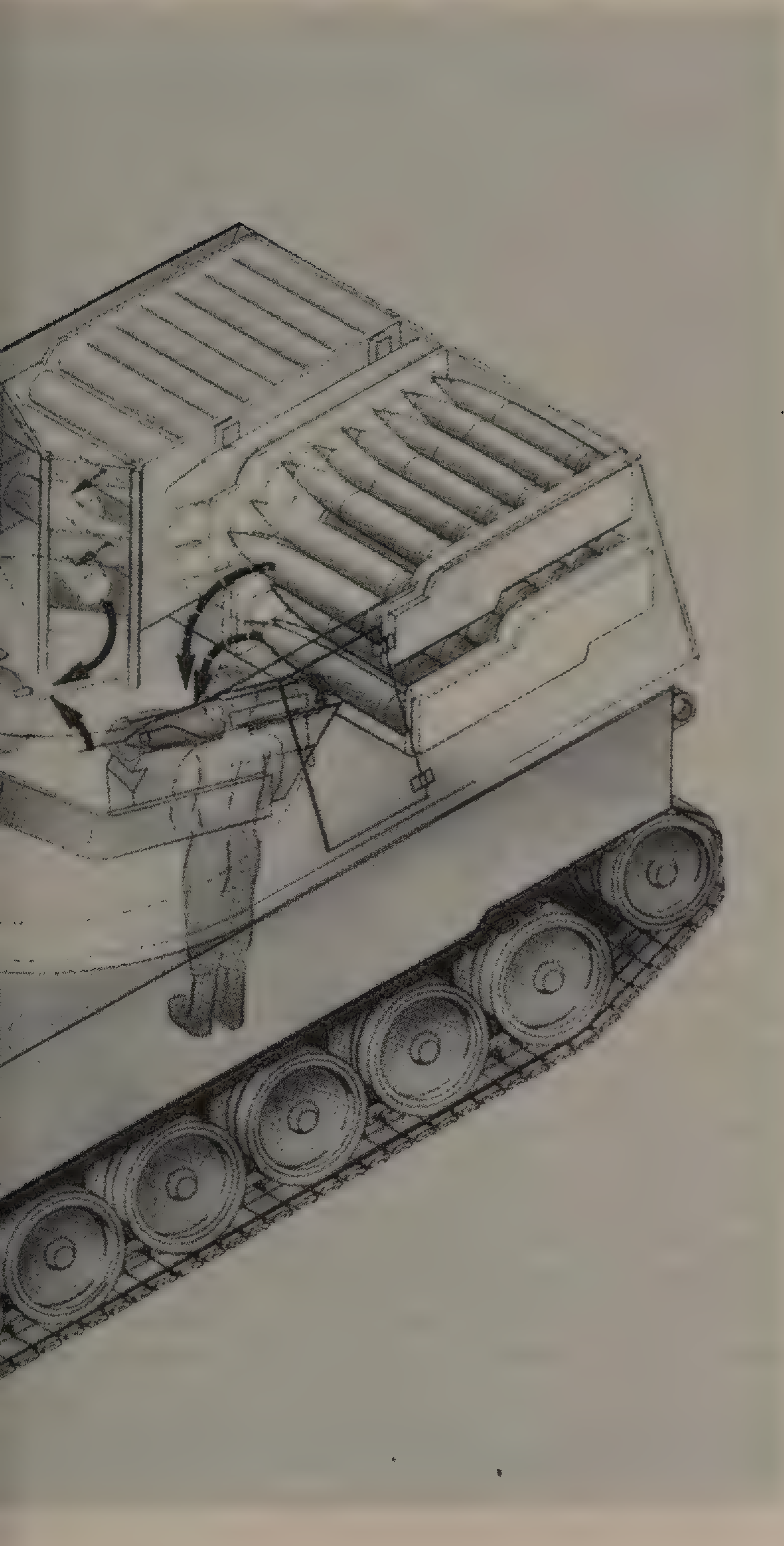
The Israelis are following the US work very closely, but since their tactical demands differ from those of the Central European front, their priorities are accordingly modified. They will be happy to settle for the improved 39-calibre ordnance, with a few minor modifications to the mounting, a simpler fire-control system and no air conditioning. But they demand a greater ammunition capacity – at least 50 rounds – and will thus have a considerably larger turret bustle containing 25 rounds, the remainder being in the hull. Since their operational procedure foresees long static

▶ A proposed design for the M109A5, one of several proposals in the Howitzer Improvement Program. This design is due to Rheinmettal of West Germany and Norden of the USA and involves semi-automatic loading.



periods of action from dug-in positions, an auxiliary generator will provide power for the mounting without running the main engine. A semi-automatic loader will be fitted, and the fire extinguishing system will be completely automatic.

Various mock-ups and technology demonstrators have been constructed since the development phase of HIP began in1986. By early 1990 eleven prototypes will be under trial; four with the XM284 ordnance, five with XM282 and 283, and two to the Israeli specification. Depending upon the outcome of these tests, the selected design will go into production in 1990. The new weapon will be standardized as the M109A5, and the US Army will then begin a programme of upgrading some 1,700 of their existing M109s to the new standard, a task which they hope will be completed by 1996.



The US Army currently has something in the order of 3,000 M109s of various vintages, and thus the HIP programme will modernize just over half. The remainder will be replaced in the late 1990s under the Advanced Field Artillery System (AFAS). At the present time there is little firm detail available on AFAS, and, indeed, it has prematurely been reported dead on more than one occasion. The initial announcement, in 1987, stressed two basic principles: first to reduce man-to-weapon ratios, and secondly to enhance survivability. Lesser requirements were increased range, a high rate of fire and a smaller detachment compared to existing systems, a mobility as good as the tanks anticipated to be in service by the end of the 1990s, the ability to withstand nuclear effects short of a direct hit, and the ability to be carried in a C141 Starlifter transport aircraft. Within this somewhat broad remit, anything goes: robotics, artificial intelligence, liquid propellants, electro-magnetic propellants and anything else that promises ballistic enhancements will, it seems, be investigated and evaluated.

Two subsidiary projects to this programme have been seen so far: ISAS (Integrated Smart Artillery Synthesis) and HFHTB (Human Factors Howitzer Test Bed). Both were more in the nature of breadboard models rather than serviceable weapons, but they indicate the way that various concepts are being explored.

ISAS was simply an automated robotic howitzer; it was basically an M109 which had been considerably modified so that it could be operated by a two-man crew either on the vehicle or nearby, and all operations of selecting and loading the ammunition were performed by an hydraulic robot system. Work on this system had, apparently, begun before AFAS was conceived, but fits well into the AFAS concept. It is anticipated that an equally robotic ammunition resupply vehicle will shortly be demonstrated.

The HFHTB has been developed by the US Army's Human Engineering Laboratory (HEL) and is aimed at

reducing the number of men required to operate a howitzer, and improving the efficiency and survivability beyond the levels established by the HIP programme. The equipment was unusual in using the chassis of an old M108 105mm howitzer, re-engined with a gas turbine, and carrying a much-modified M109A2 turret. The new engine gives more power and better agility though without any increase in top speed. The recoil spades and gun barrel travelling clamp are remotely controlled, so that there would be no need for a crewman to leave the vehicle in an NBC environment; moreover the entire vehicle is designed for operation by two men, plus a driver, so that automating these tasks leaves them free for other things. There is an automated loader/rammer system and an autonomous fire control system which is enhanced by having a GPS Navstar satellite receiver to allow frequent updating of the inertial navigation system. The fire-control computer is considerably more powerful than any previous type, and, coupled with new high-speed elevation and turret azimuth drives, has the ability to fire 'multiple time-on-target' missions. This enables the howitzer to fire four conventional projectiles in succession, at different elevations, calculated so that the four shells arrive at the target at the same time. In effect, this allows a single howitzer to produce the same result at the target as four conventional weapons out to about 60 per cent of the maximum range.

One of the problems of widely dispersed artillery is their local defence. A concentrated battery of artillery can be relatively easily defended, but scattering weapons wide distances apart, and manning them with no more than three or four men, means that they cannot be protected by wire and weapon pits and spare gunners with light machine-guns, or even by helpful local infantry. As a result, the HEL design incorporates a 25mm automatic cannon on the roof, remotely controlled from inside the vehicle. This can be used for ground or air defence and is provided with night vision sights observed inside the vehicle on a video monitor, the gun being controlled by a joystick operated by the gunner, with an overriding control available to the crew chief. The main armament (currently the standard 39-calibre howitzer) is also joystick-controlled and provided with a stabilized direct-fire sight incorporating a laser rangefinder and low-light TV camera, displaying its picture on a video monitor in front of the gunner to complete the laying.

Other concepts under examination include a regenerative liquid-propellant howitzer design, and an entirely novel concept based upon the M2 Bradley MICV chassis with a combined turret and vehicle cab traversing on top of it, the howitzer pointing to the rear of the vehicle.

The eventual decisions on ACAS are still several years away, and doubtless more elements, including new ammunition concepts, will be unveiled as the project moves along. Certainly there is no shortage of innovative ideas; whether they can all be made to work, either individually or collectively, is another matter.

At the same time as all this effort is being poured into a new self-propelled howitzer, a 'Future Lightweight Towed Howitzer' in 155mm calibre is also being developed. The need for this was first mooted in 1985, the US Army demanding a weapon suitable for deployment with their light divisions. The principal demand is that the weight should be reduced to not more than 4,082kg so that the weapon can be underslung from a UH-60 Black Hawk helicopter. So far as ballistic performance is concerned, the Army is quite happy to accept the same range and the same family of ammunition currently used by the M198 howitzer. Later the US Marine Corps expressed interest in this project, though there have been recent reports that they are now showing interest in development of an entirely new weapon rather than the US Army's solution of placing a new carriage beneath the existing M198 barrel. Some urgency was injected into these programmes by a decision, early in 1988, to terminate production of the M198 howitzer. Since the Army had requested 88 new M198s in 1989 and the US Marines another 94, the termination of production has left them a long way short of their requirements, and the production of the new lightweight designs has become even more pressing. It was anticipated that prototypes would be tested, a choice made and production begun early in 1990, but this programme appears to have slipped.

As implied above, there are undoubtedly other programmes of which we know nothing, or so little as to be able to say nothing of significance. It is known, for example, that the Japanese are developing a turreted self-propelled howitzer using the barrel of FH-70, but at the time of writing nothing firm has been made public. But the information given above is sufficient to indicate the way that minds are working and the directions in which research is being pointed.

AMMUNITION

One of the favourite maxims of gunnery instructors is, 'The shell is the weapon; the gun merely a method of transporting it to the target,' and like most maxims it is trite but true. Or, on a less refined level, as a troop sergeant explained it to me in my recruit days, 'The only way you can hurt anybody with a gun is to run it over his foot; it's the shell that does the real damage.'

If the purpose of artillery is to support the other teeth arms, the projectiles must be designed with this in mind and designed to produce the effect that will assist the infantry or the armour in their task. In earlier days this was achieved by what might be called a 'broad brush' approach; do sufficient damage and some of it is bound to be useful. It was not until the First World War that field artillery ammunition began to be designed with more specific tasks in view. (I specify field artillery, because coast defence artillery had always been conscious of the peculiarities of its targets and thus had a selection of projectiles to deal with armoured ships, unarmoured ships, landing parties and attack from the land side.)

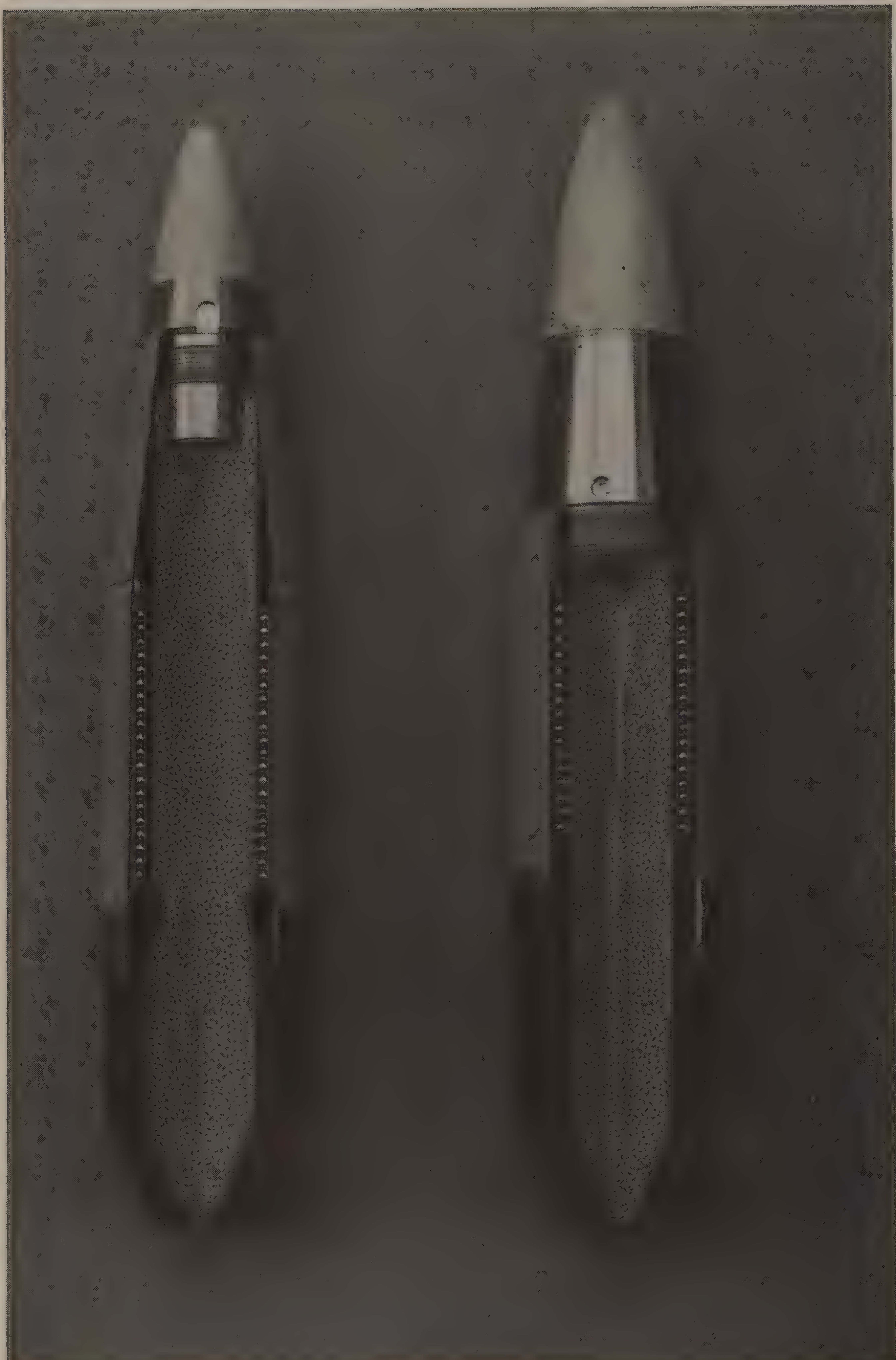
From the middle of the 19th century the standard projectile for field guns was shrapnel; this was because the prime target was the enemy's troops, marching in columns, forming squares, deploying, skirmishing, performing all manner of manoeuvres but *always in the open*. In these circumstances shrapnel was the ideal mankiller, delivering the effect of massed musket fire at long range; indeed, if troops still manoeuvred in the same way today, shrapnel would still be the standard, for nothing else was quite as effective. But, beginning with the South African War and becoming standard operating procedure in 1914–18, troops no longer massed and manoeuvred in the open within artillery range; they went into trenches or took cover in various ways, and the shrapnel shell was no longer the solution.

Howitzers had always fired explosive shell, since their prime task was the demolition of field fortifications and defences, to let the guns fire shrapnel at whatever was thus exposed. And in 1914–15, when the shrapnel firing guns were cheated of their targets, the howitzers worked overtime to fire high-explosive shells behind cover so as to effect the desired execution. The guns then demanded HE shell as well, and when the post-Great War generation of guns was designed, shrapnel was ousted and HE became the standard projectile and has remained so ever since.

The demise of shrapnel, it might also be said, had its effect upon the design of guns. Shrapnel needed to be burst about 30 feet above the ground, with the shell pointing downwards at a slight angle, in order to be effective, and a low-trajectory gun was perfectly satisfactory for this type of shooting. But once high explosive became the standard, it was necessary to provide the weapon with trajectories that could drop the shell down behind cover, and field guns had to be so built as to achieve greater elevations than the 15° to 20° which hitherto had been sufficient.

The 1914–18 war brought about a variety of new tactical problems, to which the artillery had to find solutions by way of specialized shells. When the infantry demanded concealment, smoke shells had to be developed; this was scarcely new, since smoke-producing 'carcasses' had been fired from cannon as far back as the 17th century, but a smoke shell capable of guaranteeing concealment was something else. Gas warfare brought the gas shell, night attacks the illuminating shell (then, and until the 1960s, known as star shell in British service) and the flare shell, the difference being that the star shell produced a white light for illuminating purposes, the flare a coloured flame for signalling and indicating. The arrival of aircraft led to anti-aircraft guns and the development of incendiary shells (to ignite Zeppelins) and tracers so that the gunners could see by how much they were missing, both devices being later assimilated into field artillery. Tanks, though, were still attacked by HE shell, since this could do ample damage to the tanks of the day; it was not until the early 1930s that anti-tank ammunition became a separate study. Indeed, as late as 1926 the official *Textbook of Ammunition*, in a historical discussion of the development of armour-piercing shot, referred to the contemporary design, first issued in 1887 and but little changed in subsequent years, as having been declared obsolete (in favour of AP shell) in 1921 and commented, 'With its passing, the curtain is rung down on a phase of projectile evolution which had held the stage for more than 500 years.' Within another five years the study of AP shot as an anti-tank missile had begun and has progressed steadily ever since.

The other major ammunition innovation to come out of the First World War was the mechanical time fuze. Prior to the war, time fuzes were always combustible: they used an adjustable train of gunpowder to regulate the time of bursting the shell. War experience showed



An example of pre-fragmentation: 40mm anti-aircraft shells. (Fabrique National SA)

that under certain conditions – long ranges and high trajectories – the gunpowder fuzes became unreliable, and the German gunmaker Krupp developed a clockwork fuze. Inevitably a malfunctioned specimen was picked out of the Flanders mud one day in 1917 and sent back to Britain for examination; the secret was out, and work began on a British mechanical time fuze. Nothing was achieved during the war, but the design was brought to a workable state by the early 1920s and a few hundred made for tests, after which financial stringency made it necessary to put the design back on the shelf against the day it might be needed. The British told their allies, of course, and both the French and the Americans began working on their designs – which suffered the same fate.

The Second World War saw more ammunition innovations. The same types of shell which had served in 1914–18 served again in 1939–45, though with improved designs, and some new ideas came along. The shaped-charge shell, for the defeat of armour, was common to all combatants, and the British developed the squash-head shell for the same purpose. An astonishing variety of armour-piercing kinetic energy projectiles for the defeat of armour appeared, as did discarding sabot and rocket-assisted shells for long-range artillery fire. Mechanical time fuzes came off the shelf and became reliable, and then were shouldered aside by the development of radio proximity fuzes.

But throughout all this development, the fundamental shape and mechanical features of the projectiles (except for some of the highly specialized anti-tank shot) remained more or less the same; a gunner from the 1890s would scarcely have been baffled by a standard HE shell with percussion fuze of 1945, since it exhibited more or less those features to which he was accustomed – a steel body, a copper or gilding metal driving band pressed into a dove-tailed seat, exploders in cotton cloth bags inserted into cardboard tubes in the centre of the poured explosive filling, simple mechanical fuze screwed on top, with cardboard and glazed linen washers to take up space and avoid friction – there was very little that was really new in the projectiles of 1945. Or, for that matter, those of 1955. But by 1965 things were beginning to change, by 1975 the wind of evolution was blowing strongly, and by 1985 the poor Victorian gunner would have scarcely believed his eyes.

In fact, careful study of historical records will show that many of the innovative design features of present-day ammunition were thought of many years ago; the trouble lay in trying to make them work within the technology framework of the period. Advances in metallurgy and mechanical engineering, even in basic scientific research, have allowed many elderly ideas to be brought out, refurbished, and put into practical use. The shaped charge, for example, was first explored in the 1880s, but it was 1940 before anyone managed to make a practical military projectile utilizing the principle; a taper-bored gun and projectile was patented in 1903, but, again, it was the late 1930s before it became a practical weapon. Similarly, such things as base bleed, hemispherical shells, stub wings, long rod penetrators and electronically set fuzes can be picked from the patent applications and research records from 1900 onwards, but it is only since 1960 that any of them have been turned into workable devices.

High-Explosive Shells

The contemporary high-explosive (HE) shell differs only in detail from its predecessors, but that detail is significant. Small details can be responsible for considerable improvement in projectile design; the introduction of the boat-tail – the slight taper of the shell body behind the driving band – in the 1920s gave an enormous increase in range to contemporary guns, and yet the physical change is no more than a slight reduction in the quantity of metal and a slight reduction in the base diameter of the shell. The trick lies not so much in the physical change but in appreciating the underlying significance and the effect it is likely to have.

The object of the HE shell is to cause casualties and material damage by a combination of blast and fragmentation. To achieve this the shell body is of steel and is filled with high explosive. So far, so good, but the selection of the correct grade of steel and the appropriate explosive is critical; and not only from the military point of view, but from the economic point of view as well. It might very well turn out that the optimum result could be achieved by using a titanium projectile filled with some very exotic explosive; but the expense both in material and in manufacturing processes, would be such as to make the design quite impractical. For it must be borne in mind that the time of greatest demand for shells will be during a war, which is also the time of greatest demand for many

A range of artillery projectiles from Buck Werke of West Germany. From right to left: 105mm howitzer M1; 155mm howitzer M107; 155mm howitzer FH-70 pattern; 155mm howitzer ERFB.

other vital munitions, some of which might well be competing for the titanium and the exotic explosive. So the design has to be one which can be manufactured in quantity, at speed, in war, and still be reliable and effective.

The manufacturing base of the country can have its effect here; during the Second World War British HE shells were made from '19-ton steel', a figure referring to the yield point and which was a convenient way of describing the particular steel. This was selected in the design stage because it was cheap, available, and capable of being worked by relatively simple methods – the ideal situation for British industry at that time. American design, on the other hand, was based on the availability of 23-ton steel because the US engineering base was attuned to handling this grade. Without going too deeply into the metallurgy, what this meant in practice was that due to the greater strength of the American steel the shell walls could be made thinner, so that there was more cubic capacity within the shell and it could take a heavier payload of explosive; a bigger bang. But, as another aspect of the same question, the stronger steel demanded a more violent explosive to ensure optimum anti-personnel fragmentation. British shells could be filled with amatol, comparatively weak, and still give adequate fragments; this was fine, since amatol was a cheap explosive which economized on scarce TNT, a situation which fitted well with the relatively poor TNT manufacturing capacity which existed in Britain prior to 1939. The Americans, however, with their larger manufacturing base and later entry into the war, were able to ensure adequate supplies of TNT and even more powerful explosives, so that they were able to utilize the optimum explosive for their harder steel shells.

However, this sort of solution was necessary because of the type of artillery being employed at the time and the tactical systems in vogue. The 19-ton steel shell

might not have been a technological wonder, but given 500 guns and a few thousand tons of shells to fire off at a given target, the final effect would be quite satisfactory. Today, as we have seen, the prospect of mustering 500 guns on the battlefield for a particular target are pretty remote, so the same scale of ammunition expenditure is unlikely to occur. Therefore the design of shell today is rather less affected by economists; although there is still some degree of economic restraint on the designer – no titanium – the enormous ammunition expenditures of former wars are unlikely to occur, and thus the demand for a design capable of being made in blacksmiths' shops and small engineering factories is no longer valid.

The other side of the coin is that in order to compensate for the smaller quantity of ammunition being fired, the individual projectiles must be that much more effective. This is, of course, helped by the improved accuracy of today's artillery; instead of firing 50 rounds and hoping that 10–15 of them will strike the target, today's gunner fires one round and is quite sure it will hit the target. So that three or four modern shells will achieve the same destructive effect that 50 did 50 years ago.

It follows from this that the designer has two vital factors in view from the start: first the terminal effect – how much damage the shell is going to do – and secondly the accuracy – whether it will go where it is pointed. After that the routine requirements are lined up in whatever order the designer's masters think appropriate – safety in handling and transit, safety in the bore, reliability, good shelf life, absence of economically critical materials in the design, ease of manufacture, cost, and so on and so forth. But the two first requirements of effectiveness and accuracy outweigh the remainder; it is of little use to have an inexpensive, easily manufactured, safe projectile with high accuracy if it fails to have any effect at the target, or one with devastating power which cannot fly straight. And the records of experimental establishments can provide some entertaining examples of both kinds.

To add to the problem, though, today's designers are being pressed more and more for a third vital ingredient in the mixture – range. In times past maximum range was not always considered to be vital; there was very little point in having a field artillery piece with a range of, say, 20 miles, if the observers couldn't see that far. Heavy artillery was often capable of considerable ranges, but all the firing was done 'off the map' without visual observation, purely on the chance that the selected target was likely to be an enemy concentration point, railway junction or some other map-obvious possibility. The use of field artillery at its maximum range was uncommon, purely because of the observation aspect. You couldn't shoot what you couldn't see.

Today, however, the observation capability has been considerably improved by the use of sophisticated electronic and optical devices, by the use of aircraft and remotely piloted vehicles, by radar and by other methods. The accuracy of shooting 'off the map' has improved because of better maps (aided by satellite observation) and by better systems of compensating environmental effects. So that now there is a constant demand for greater range; this demand is, in itself, nothing new, but designers in the past were wise enough to ignore much of the clamour for they were aware that an excess of range was incapable of being used and was not a practical factor. Today's demand for range is more serious; the gunners know they can use it and the designer knows that he has to be able to produce the extra kilometre or two if only to outrange the likely opposition.

There is one final constraint on today's designer which ought to be mentioned; he is undoubtedly working within the confines of a specific weapon, with chamber volume, calibre and the other mechanical facts of the weapon incapable of being changed. In years gone by the designer was generally given a demand for a particular range, a specified probable error and an ideal lethal area and told to get on with it. At the end of his slide-rule and drawing-board exercises, he returned to his master and said, 'Sir, you require a 6.875in howitzer of 32 calibres length,' and the gun designers were then called into the business. The days of a free hand from scratch are virtually over, and today's designer is pointed in the direction of the NATO standard chamber, the FH-70 howitzer or some equally fixed point of reference and has to work his oracle within that framework.

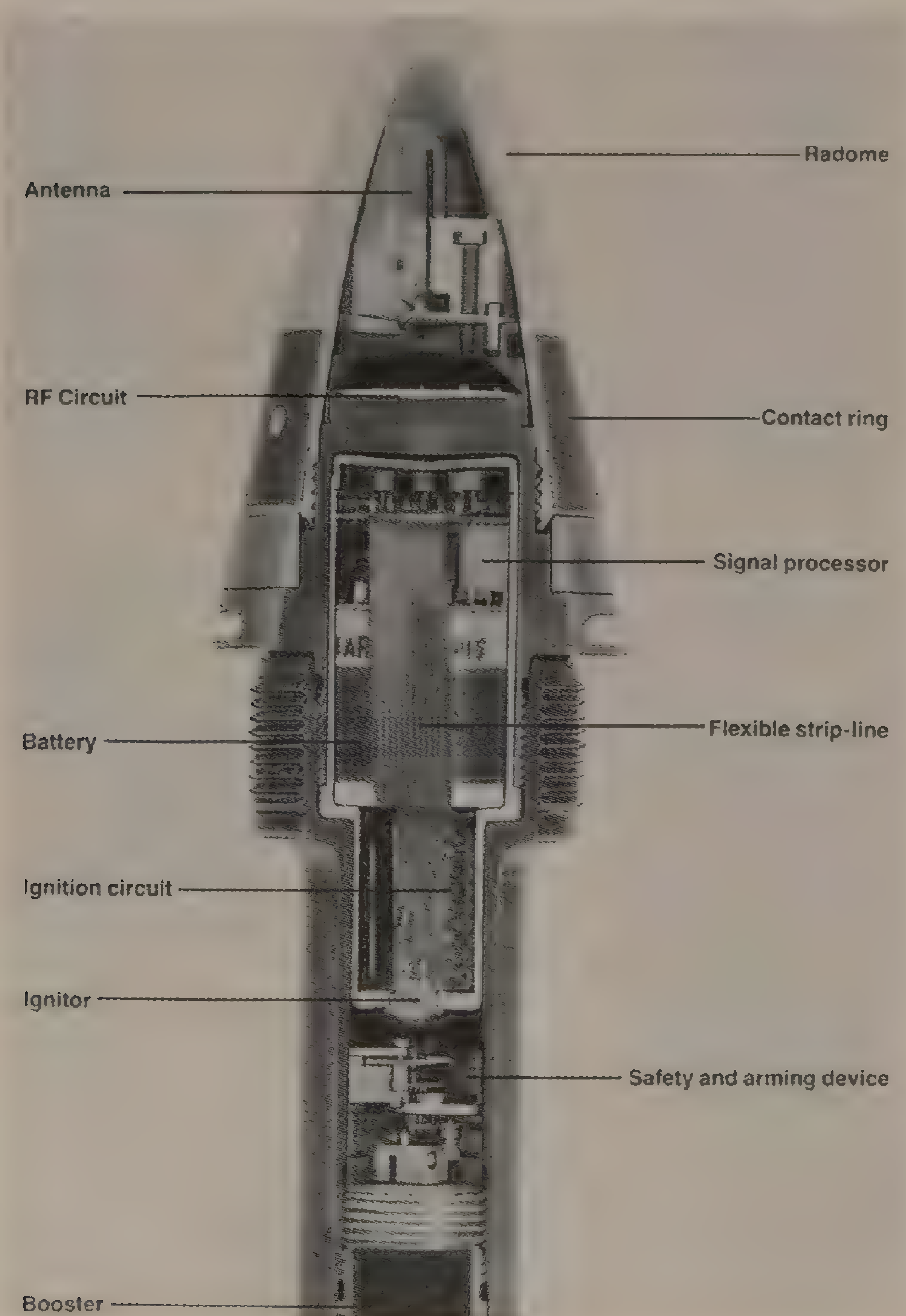
Let us therefore now look at ways in which terminal effect and long range can be achieved. Accuracy is something that is less amenable to examination; it very often happens that an initial design is far from accurate but responds to minor changes in contour or driving band or balance or spin rate, and even the designers are hard put to say precisely what spells the difference between an accurate shell and an inaccurate one. Some

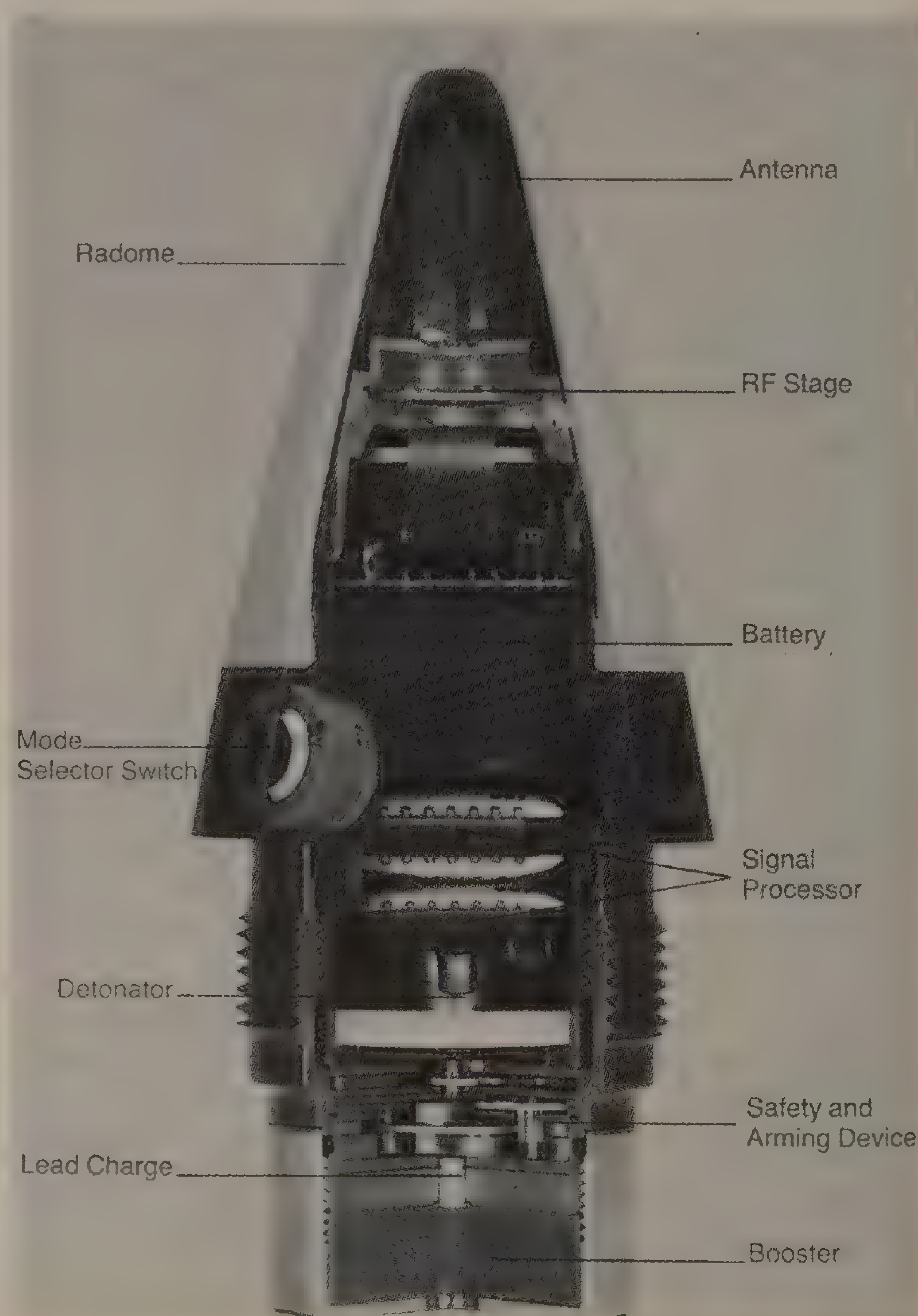
weapons seem to settle all the problems without much thought and produce startling accuracy from the beginning – the American 8in howitzer M1 is a notably accurate weapon and always has been. Others start life under a cloud and only dedicated and delicate work by the designers achieves the desired accuracy in the end.

Terminal effect, however, can be designed in and precisely measured at every stage of development, and the corrections to defects are fairly simple matters. The optimum size and distribution of fragments can be arrived at by careful consideration of the strength of steel and brisance of explosive, followed by practical testing in which the shell is detonated inside an armoured cell so that all the fragments can be collected and weighed, and by tests in the open in which the shell is detonated within a series of screens so that distribution of fragments can be assessed. Adjustments to shell wall thickness and contour, steel strength and explosive strength can all be made until the desired terminal effect is achieved. This is a well-understood process and unlikely to cause many problems.

However, it has to be allied to the range and accuracy question; the perfect shape of shell for delivering fragments might very well turn out to be a totally unworkable shape for long range or accurate flight, and inevitably there is a certain degree of compromise, depending upon which particular aspect is considered most important. Moreover, what a projectile does when stationary in a test rig is not necessarily the same as what will happen when the shell is spinning, moving forward, and in air of varying density. So that when all the stationary tests are completed, the results still have to be confirmed by live firings against target arrays.

The breakup of a shell into fragments is empiric, at best. Varying degrees of homogeneity in the metal itself, varying effects of the detonation wave and the





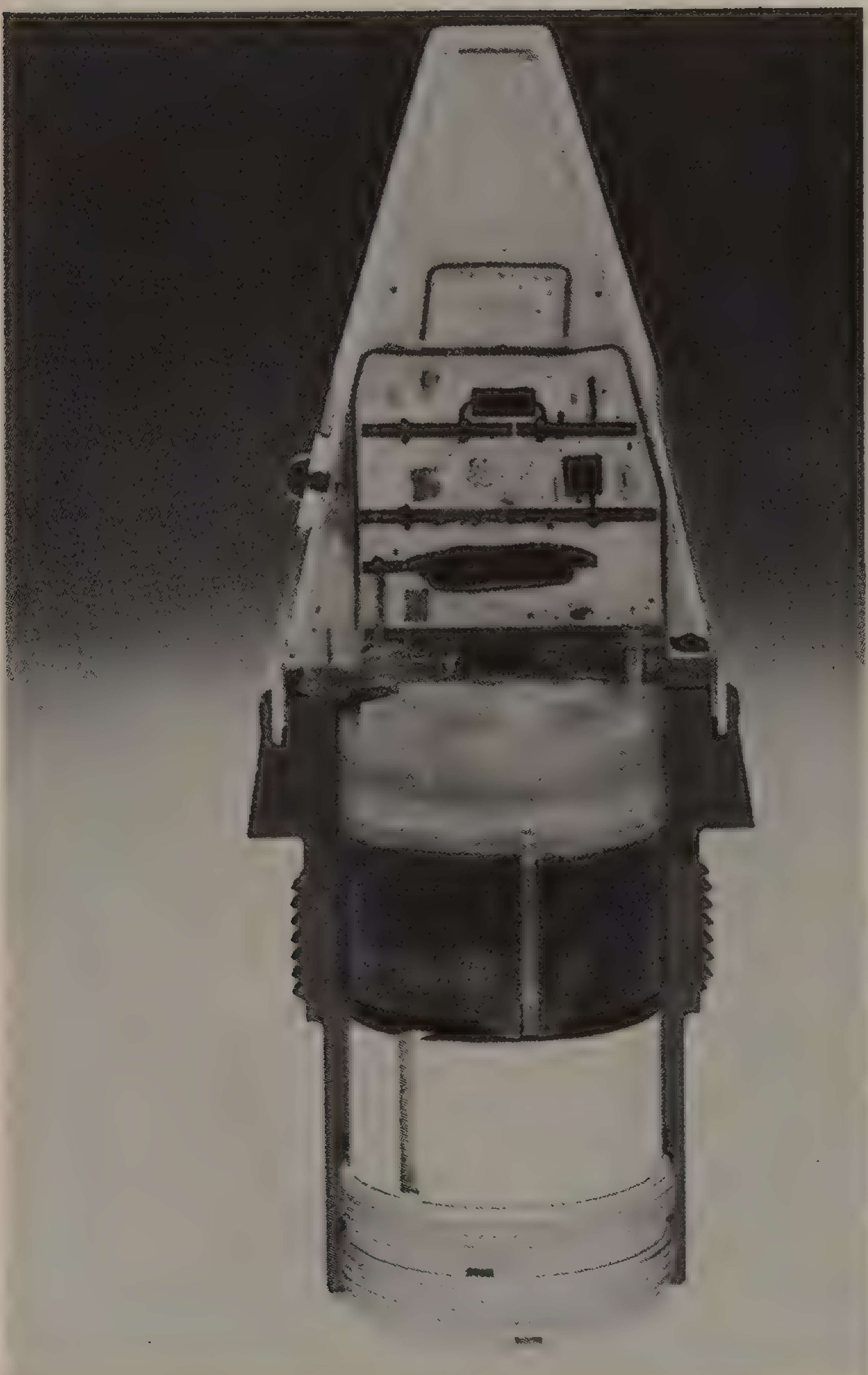
▶
Zelar, a Norwegian multi-role fuze.

◀◀
The AEG-Telefunken DM24 proximity fuze, showing the principal components. The antenna radiates energy which, when reflected from the target in sufficient strength, causes the fuze to detonate the shell at the optimum lethal distance from the target.

◀
Another AEG proximity fuze, indicating the way in which the physical size has been reduced by the adoption of solid-state electronic components.

varying thickness of the projectile walls all combine to make the generation of fragments a random affair. As a consequence, the fragments, of varying shapes and sizes, weights and centres of gravity, tend to take up trajectories that are never as regular as theory suggests, and are not capable of repetition from shell to shell. All the designer can do is arrive at a good average, as it were. One way of avoiding this element of chance in fragment production and distribution is to manufacture the fragments in advance and then incorporate them into the projectiles, distributing them so as to obtain the most even pattern on detonation. Another way is to make the explosive charge in such a way that it controls the shaping of the fragments.

To take the latter system first, we might start by considering the hand-grenade. As everyone knows, the Mills Bomb (and the American 'Pineapple' grenades and many others) has the casing deeply scored into rectangles; and everyone supposes that this is intended to control the splitting of the grenade into fragments. In fact, examination of the fragments of one of these grenades immediately shows that the scoring has no effect whatever. And if you study Mr Mills' patent applications you will see that he designed this scoring so that the grenade could be securely gripped by a muddy hand. But shortly after the Mills No 5 grenade went into service, another design, the Oval or No 16 grenade, appeared. This had the body serrated on its



◄◄
The British L116 multi-role fuze, another solid-state electronic fuze which offers a variety of modes of operation.

◄
A modern design of high-explosive shell, showing the use of pre-formed fragments held in a plastic resin matrix around the explosive filling. This also indicates the intrusion into the shell necessary for proximity fuzes.

interior surface, with a smooth outer surface, and it was soon seen that the fragments were close to the dimensions of the scoring. Internal serrations provide some control of fragmentation.

Another British grenade of the same period (1915) deserves a mention; the No 7 hand-grenade consisted of two tinplate cylinders, one containing explosive and placed inside the second cylinder. There was an annular gap between the two, and this was filled with steel scrap, which, when the explosive detonated, was propelled in all directions.

So here, in 1915, we have two attempts to control fragmentation, one by internal notches or grooves, and one by provision of fragments of the desired size.

To revert now to projectiles, the internal grooving system was revived in about 1943 for anti-aircraft use. The contemporary 3in rocket warhead was a parallel-walled shell body with a fuze at the nose and a rocket motor attached to the base. The filling was amatol or TNT and the resulting fragments were too small to be really decisive against aircraft. In order to produce fragments of a useful size, a waxed paper sleeve was inserted into the shell before filling commenced. This sleeve was moulded into a series of v-shaped depressions about 1½ inches long by about one-third of an inch across, and the open face of the depression was pressed against the shell wall; the high explosive, poured into the inside of the sleeve, filled up around the depressions, and the effect was to produce a series of linear shaped charges. When the explosive detonated,

the depressions focused the detonation wave into a series of cuts in the shell body, so carving it up into well-defined rectangular chunks of the size and weight ideally suited to damaging aircraft. The system worked well, but was abandoned when the 3in rocket went out of use and appeared to have been forgotten. It was revived in the early 1980s by the South Africans who produced a similarly shaped plastic liner for the warhead of an air-to-air rocket. The defect with this idea is that it more or less demands a perfectly cylindrical projectile casing, since attempting to produce a liner which curves to fit the interior wall of a conventionally shaped artillery shell appears to be impossible unless the design of the shell incorporates a removable base to allow loading from the bottom, something modern designers do well to avoid.

Thus the choice falls upon the provision of fragments to a predetermined size and distribution. As with the rocket, so with the grenade; the idea seems to have been abandoned after the No 7 grenade went out of service, probably because the design was intended simply as a manufacturing expedient rather than as a method of fragment control. But it returned in the late 1940s when the US Army developed their M26 grenade and used a coil of tempered, notched wire inside a thin sheet steel casing. In the 1960s came a few rifle grenades using steel balls held in a matrix of epoxy resin inside a thin steel body, and after that the idea gained in popularity. So far the idea seems to be confined to small calibre anti-aircraft projectiles, in order to increase their lethality by controlling the fragment size, and thus improving their hit probability, but there are one or two anti-personnel projectiles using this system. The 84mm Carl Gustav anti-tank gun and the 106mm recoilless rifle M40 are weapons that have been given pre-fragmented projectiles for use in their secondary anti-personnel role, and both use a quantity of steel balls set into a matrix inside the shell wall. However, in both cases the projectile is parallel-walled and thus a relatively easy proposition for filling; shells with more conventional curved interior contours are not so easy to line with an even layer of balls and, so far as I am aware, nobody has yet produced a major calibre pre-fragmented shell for conventional field artillery employment.

Designing for range is productive of more interesting visual effects and allows designers to offer various solutions. There are, of course, two ways to improve the performance of any gun; one is to do something to the gun and the other is to do something to the ammunition, and it might be as well to deal with the various gun options first.

Improving the performance of a gun means, quite simply, increasing its muzzle velocity. The first, and most simple solution, is to increase the size of the propelling charge or develop a more efficient propellant while still operating the gun at the same chamber pressure. This, in round figures, demands a four-fold increase in propellant quantity to obtain an increase of 60 per cent in velocity, and it carries with it several gross disadvantages in the shape of erosive wear, redesign of chamber and cartridge case and economic production of propellant.

The next method is simply to increase the length of the barrel, so as to allow the propellant gas longer time in which to expand behind the projectile. To obtain the same 60 per cent increase in velocity would require an increase in barrel length of 300 per cent – a far from practical solution.

An increased chamber pressure combined with a moderate increase in barrel length will increase velocity. A 50 per cent increase in pressure and a 50 per cent increase in barrel length will give the same 60 per cent increase in velocity, but, again, it is scarcely a practical solution. If the user is satisfied with a smaller improvement than the 60 per cent figure (which is only used here because it produces some easily assimilated demands in construction), this combined pressure/barrel length solution can produce workable answers. It is, after all, the method by which the 155mm howitzer has crept from 35- to 52-calibre length over the past twenty years.

Other possible gun solutions include rifling the bore with a few deep and wide grooves and then fitting the shell with suitably shaped ribs which will engage in these grooves to develop spin. This allows the use of extremely powerful propelling charges which would deliver such a forward acceleration that the conventional copper driving band would shear and fail to develop spin. Or it is possible to produce a gun barrel which tapers in calibre from breech to muzzle; this reduces the effective area of the projectile exposed to gas pressure, and with a correctly calculated charge, which maintains pressure or even increases it during shot travel, this develops a greater pressure per unit of area and thus generates a higher velocity. Both these solutions have been tried in service weapons (the German 21cm K(E) and 28cm K5(E) and British 13.5/

8in long-range guns used the deep groove/ribbed shell, the German 28mm, 42mm and 75mm anti-tank guns the taper-bore solution) but they mean long and difficult manufacture and highly specialized ammunition and are only valid for small-quantity special-purpose weapons.

And so it all comes back to the ammunition; again, there is a simple solution – make the projectile lighter. Halve the shell weight and you will increase the muzzle velocity by 40 per cent, but this is a self-defeating method, since the lighter shell loses in ballistic coefficient – its carrying power – and thus loses velocity very rapidly in flight, so although it may start off faster it fails to stay the course and finishes up with less range than the standard projectile. Moreover, there is little virtue in increasing range at the expense of terminal effect.

Given a specific muzzle velocity, two things combine to bring the projectile to earth: gravity and aerodynamic drag. We can do little about gravity, but drag can be countered by careful design. Drag makes its appearance in three places; the nose of the shell, the base of the shell, and the surface of the shell. Nose drag is due to the point of the shell cleaving its way through the air, and it only begins to assume major dimensions when the shell is travelling at supersonic speeds, when it builds up a Mach wave. Base drag is most in evidence at subsonic speeds and is due to the air, cloven by the passage of the shell, swirling round the base to re-unite in the wake of the shell's passage. At supersonic speeds there is also a minor Mach wave developed by the tail of the projectile. Surface drag, or skin friction, is less, compared to the other two, but is certainly present and makes itself very obvious when driving bands are badly designed so as to protrude carelessly into the air stream. But apart from care in designing the driving band not a lot can be done to reduce surface friction, and experimental work has shown that changing the projectile's shape, while it can have significant effects on the other forms of drag, makes little difference to the surface drag.

Field artillery shells may start out at supersonic velocities but they spend most of their flight at subsonic speeds, so that base drag becomes the most significant enemy. A fine raper at the nose is the best defence against nose drag, but too fine a taper will detract from the payload capacity, will play havoc with the centre of gravity and will probably reduce the parallel-walled section of the shelf if carelessly applied. To provide adequate support and guidance during its travel down the bore the shell must have a cylindrical section at least 1.3 calibres long; the total length of the shell must lie between 4.5 and 7 calibres, otherwise instability sets in; the reduction in diameter at the base will be of at least half a calibre length; so the sum of all this is that there is between 2.7 and 5 calibres length available for the nose, and the wise designer makes sure that he has more than the stipulated 1.3 calibres of support and leaves adequate space for the filling.

During the course of this century velocities have increased, and, in step, the shape of the standard shell has become finer at the nose. The nose shape is 'ogival', an architectural expression for a pointed arch, and its shape can be accurately described by reference to the radius in calibres. There is, of course, more to it than that; the ogive (i.e., the curved portion of the shell's nose) can be 'simple' or 'compound'. In a simple calibre-radius head (crh) the curve is struck at a particular radius from a point level with the shoulder – i.e., the point at which the parallel walls turn into the nose curve. This gives a nice simple shape, but a somewhat abrupt translation between curve and parallel wall, and would be described as '–x crh' where x is the radius in calibres.

A compound crh, which is today's norm, has the actual curve struck on a fairly large calibre radius but within the same overall length as that obtained by a lesser simple radius. This is achieved by moving the locus back behind the shoulder and at the distance of the larger value. As an example, a 155mm shell of simple 5crh head would have the head struck on a radius of 5 × 155 = 775mm. A 155mm shell of compound 5/10crh would have the head struck on a radius of 1550mm, but the locus of the curve would be so positioned that the length of the head was exactly the same as that of the 5crh shell. Most of today's 155mm shells have a compound 8/16crh head, or one very close to that value, since this appears to give the best compromise between nose drag reduction, balance, and payload.

Base drag is first attacked by reducing the diameter of the base by tapering the shell behind the driving band – boat-tailing or streamlining are the terms generally used to describe this in shorthand form. Like everything else, this has to be a compromise; too much taper would be very beneficial in reducing drag, but would lead to problems with internal ballistics and achieving proper spin stabilization as well as producing

▶
The 155mm howitzer XM785 rocket-assisted nuclear projectile, showing the rocket assembly at the base. This ignites 7 seconds after firing, so allowing the shell to settle in a steady flight and reduce the chances of yaw-induced inaccuracy.

difficulties in manufacture. So a taper of between four and six degrees is generally accepted as one which makes a considerable improvement in the drag figures but without upsetting anything else. Streamlining the base cuts down drag by leading-in the airflow to the vacuum behind the shell in a more orderly fashion; a square-cut base causes the air to swirl in and generate maximum drag.

The next step is to recess the shell base in a hemispherical form, giving, if you like, a skirt to the base of the shell. This traps the vacuum within the skirt and allows the airflow to merge more smoothly in the wake. This technique was adopted fairly generally in the late 1960s with the FH-70 and GCT155 ammunition and has proved a perfectly adequate way of obtaining a worthwhile increase in range without too much manufacturing difficulty.

Another method of disposing of the vacuum is to fill it with gas. When tracer devices were first applied to artillery projectiles it was noticed that an improvement in range invariably followed, and from this the 'base bleed' technique was developed. In this system the rear end of the shell contains a cavity filled with smokeless powder, ignited by the flame of the propelling charge. The powder burns at a carefully regulated speed, generating a flow of hot gas which is 'bled' out to fill the vacuum behind the shell's base. Again, not as simple as it sounds, base bleed took several years of trial and error before it became a practicable solution, but it has now been adopted by several manufacturers and increases in range in the order of 20 per cent or more are common.

One might assume that the logical progression from base bleed would be to increase the size of the smokeless powder charge and use it to deliver additional propulsive effort by turning it into a rocket, but in fact the rocket-assisted shell preceded the base bleed by many years, having been put into service by the German Army in 1942. Rocket assistance then lapsed for some time and was revived by the US Army in the 1960s and has since been adopted by various forces. It generally gives an increase in range of about 20–30 per cent, but is liable to be accompanied by a diminution of accuracy unless very carefully designed and manufactured. This is due to the liability of the shell to yaw – for the axis of the shell to deviate from the line of the trajectory due to air pressure and slight imbalances. Should the shell be yawing off-trajectory at the instant of rocket ignition, the initial thrust will start the shell

on a new trajectory, deviant from the planned one. As a result the fall of shot will not be in the intended place; the first German rocket shell to see much use, the 28cm RoGr, increased the maximum range from 62,200 metres to 86,500 metres, a useful 39 per cent increase, but the shell was liable to land anywhere within a rectangle 800 metres wide by 13,000 metres long. Things have improved since then, but not so much that anyone is prepared to guarantee the same degree of accuracy from a rocket-boosted shell that they would from a conventional one.

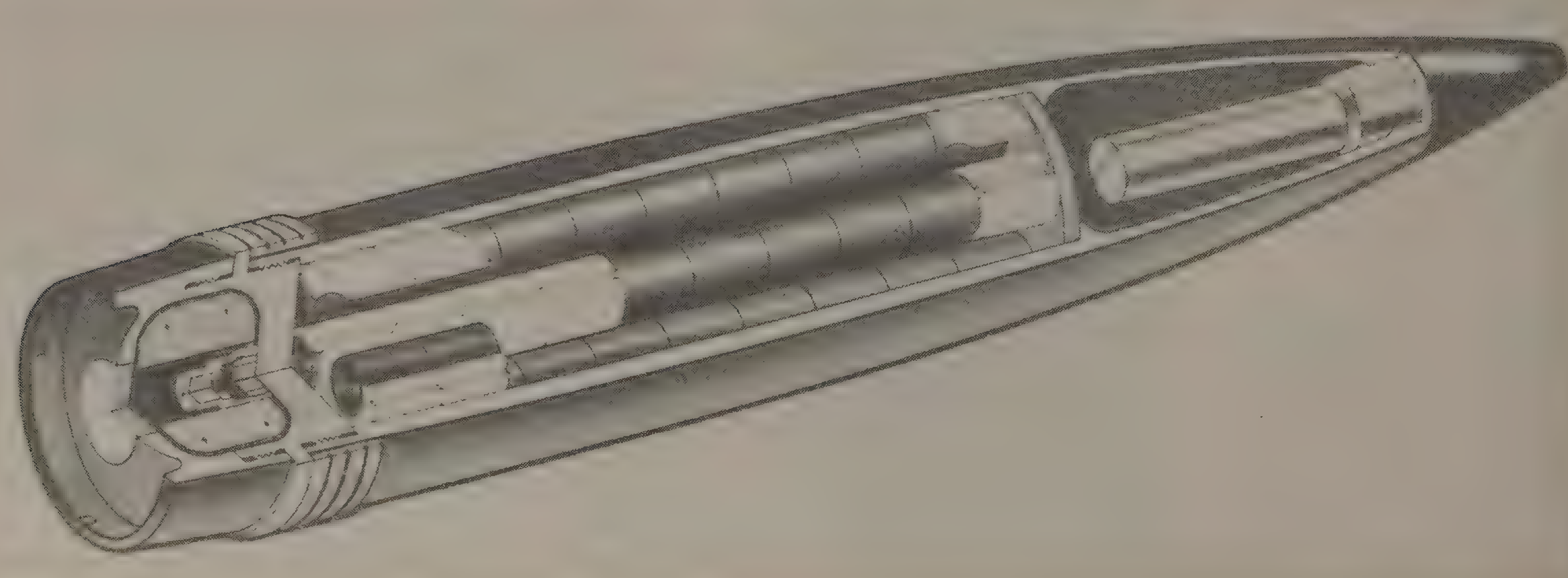
Another drawback to the rocket-boosted projectile is that putting in a rocket motor means taking out some of the high-explosive payload and thus reducing the terminal effect of the shell. More efficient designs of rocket mean that this is rather less serious than it was in the 1940s, when about half the volume of the German shell was occupied by the rocket motor, but it is still an important factor.

A variation on the rocket theme is the adoption of ram-jet propulsion, sometimes called the 'athodyd shell'. This was another German wartime development which thereafter lapsed but was revived in the 1960s by the Americans, and, according to rumour, by the Soviets, but so far as we know neither has managed to come up with a practical design. The ram-jet shell operates by tapping the air that is flowing past the shell in flight, passing it into a suitable combustion chamber, adding fuel, igniting it, and thus generating a jet-engine-like thrust at the rear. The jet exhaust goes some way to giving the shell a base-bleed effect, and the combination can be made to give a substantial range increase.

As might be imagined, the design is complex; a central channel or a number of peripheral channels, correctly contoured to provide the combustion chamber and nozzle, have to be built into the shell, there has to be storage space for the fuel, and somehow it has to be ignited. All this is possible in an experimental projectile, a design intended simply to prove that the ramjet idea is workable, but translating that into a practicable shell with a worthwhile payload of high-explosive, adequate fuzing, and sufficient robustness of design to survive the rough and tumble of field operations is a very different matter, which accounts for the absence of a ramjet shell in anybody's armoury today.

In view of the difficulties of manufacture and operation, any design that can produce more range without resorting to rocketry or other complex solutions has considerable attraction, which is why the ERFB design has been widely exploited.

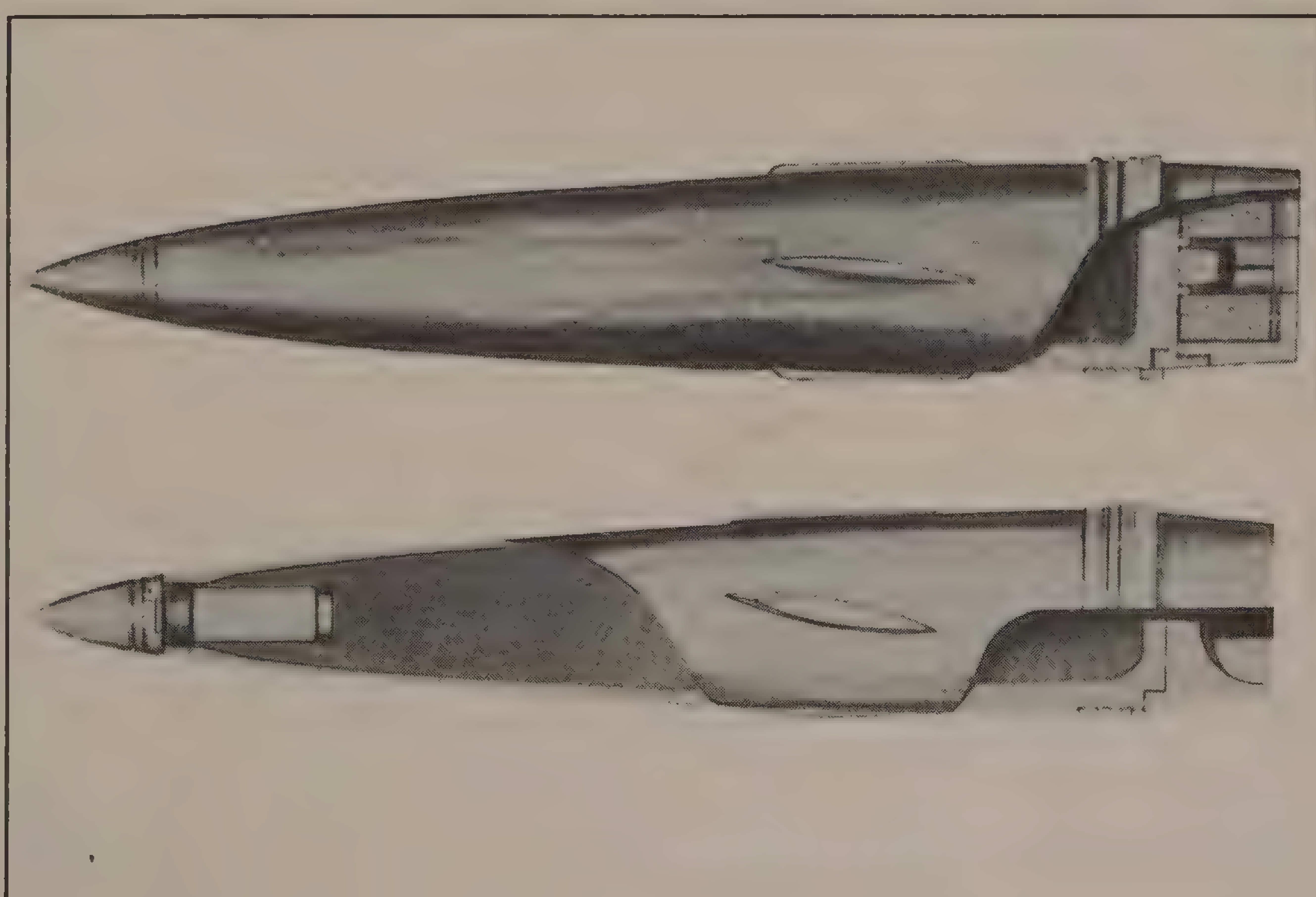
The ERFB – Extended Range, Full Bore – shell was pioneered by SRC of Canada for their GC-45 155mm howitzer. They began by developing the best profile for flight, which led them to a short body, streamlined hollow base and very long tapering ogive. This, while excellent for flight, was poor in the bore since the short body gave inadequate support. In order to steady the shell during its movement up the bore, short stubs of metal were attached to the ogive so that they rested on the surface of the bore and, in conjunction with the shell wall, gave the desired support and alignment to the shell. And so that the stubs should give the least possible interference in flight (for discarding them at



▲
Improved Conventional Munitions: the 155mm M483A1 carries 64 M42 and 24 M46 dual-purpose shaped charge/fragmentation grenades.

◄
The XM864 projectile is similar to the M483A1 in carrying a number of grenades, but has the added feature of a base-bleed unit in the rear, so increasing the maximum range.

►
Two types of ERFB projectile, showing the stub wings and hemispherical base and, on the right, a base-bleed attachment.



Comparison of the conventional M107 155mm howitzer shell and an ERFB shell of the same calibre.

the muzzle was too complex) they were canted at the angle of the gun's rifling, so as to conform with the airflow due to spin, and given an aerodynamic section so as to reduce their individual drag. Now, whether it was intended or not I have no idea, but the aerodynamic aspect of the stubs proved to give additional lift to the shell, much as a set of wings might have done had such a thing been practicable, and the ERFB shell produced a useful improvement in range at a minimum cost. The term ERFB, incidentally, was adopted to emphasize that the shell was close to the conventional pattern and was not relying upon discarding sabot or other complex systems for its additional range. As early as 1976, tests with a standard M109 155mm howitzer, normal maximum range 14,600 metres, showed that an ERFB shell with the standard propelling charge could reach 15,800 metres, and with a propelling charge calculated for the different ballistic characteristics of the ERFB shell the maximum range became 19,300 metres.

Since the development of the ERFB by the Space Research Corporation, other companies have built on the idea. The current model manufactured by Hirtenberg in Austria increases the maximum range of the GH N-45 howitzer from 17,800 metres with the M107 projectile to 30,300 metres using the ERFB; addition of a base-bleed unit takes this up to 39,000 metres. Similar figures are available from the ERFB design produced by PRB of Belgium, who collaborated with SRC and are developmental successors. The only army to have actually used ERFB ammunition in combat is the South African; their projectiles are made by the Armscor organization and develop a range of 30,800 metres in the G5 and G6 howitzers; a base-bleed unit is also available which increases the maximum range to 39,000 metres.

Improved Conventional Munitions

This somewhat ornate title covers those projectiles which, while fired from the gun in the conventional manner, develop their effect at the target in a very different way from the conventional high-explosive shell. In effect, they are carrier shells loaded with sub-munitions; the shell is merely the vehicle which takes the sub-munitions to the target area and there liberates them. It is the sub-munitions that provide the tactical effect.

Development of ICMs began in the USA in the late 1960s and has since been taken up by most manufacturers of artillery ammunition. The principle is based upon the common base-ejection type of smoke shell, but instead of canisters of smoke the shell is loaded with grenades, mines or other explosive munitions. A time fuze is fitted and set to operate over the target. The fuze ignites a small expelling charge which blows off the base of the shell and ejects the contents. Centrifugal force (from the spinning shell) and remaining forward velocity distribute the sub-munitions in a more or less regular pattern beneath the shell.

The action of the submunition depends upon their purpose. The American 155mm M449A1 shell releases 60 anti-personnel grenades; spring-loaded fins stabilize each grenade so that it strikes the ground in the correct attitude, whereupon an ejection charge is fired which projects a spherical grenade to a height of about 2m, where it detonates spraying fragments in all directions. The M483 shell carries 88 shaped-charge/fragmentation grenades which can penetrate more than 60mm of armour and which also splinter so as to distribute anti-personnel fragments around their point of burst. The M692 ADAM (Area Denial Artillery Munition) shell is loaded with 36 wedge-shaped anti-personnel mines. After striking the ground each mine deploys seven sensor tripwires and then electrically arms itself. Any disturbance of the tripwires or the mine causes it to eject a spherical grenade upwards, to burst at about 2m height. The mine also carries a self-destruction mechanism, which functions after a pre-determined period of time.

For the attack of armour the M718 shell is loaded with nine 2.25kg anti-tank mines. These fall to the ground after ejection, arm themselves, and will detonate upon sensing the proximity of tanks or other armoured vehicles. If the mines are not fired during their intended life span, a self-destruction mechanism destroys them at the end of a predetermined period. In addition, a proportion of the mines are equipped with anti-handling devices to inhibit clearance.

Once this type of munition went into American service, other manufacturers in other countries began their own development and a number of designs are now on offer, including ICMs with base-bleed attachments to give increased range.

The next step was to develop an ICM projectile with more target-specific types of submunition. For the past 20 or so years, the major threat facing Western armies has been the overwhelming Soviet superiority in armour, and thus the major design effort went into the development of submunitions designed to cause major damage to main battle tanks. The small bomblet submunitions had the capability of piercing armour, but their effect was small; what was now planned was a submunition capable of killing a tank all by itself.

The result was 'SADARM' – Seek and Destroy Armour. This was a 203mm shell carrying three complex submunitions. After ejection, the submunitions each deploy a parachute so designed that the devices rotate as they fall. Each device contains a narrow field of view sensor – millimetric wave radar or infra-red – which sweeps in a gradually reducing spiral until it detects a target of the correct characteristics. Once an armoured target has been spotted, the scanning system remembers it, checks on its presence at every rotation, and when the target is within range fires a self-forging fragment at it.

The self-forging fragment is a derivation from the shaped charge, by way of a wartime discovery called the Schardin Effect. Schardin was a German ordnance engineer who developed a stand-off anti-tank mine which consisted of a cylinder of explosive faced with a slightly dished, heavy steel plate. When the explosive was detonated the steel plate was blown forward at high speed, straightening out in the process, and when it struck a tank it would punch a hole straight through the armour. Wartime trials against captured Soviet tanks gave startling results, but the device was not perfected before the war ended. Various other hands took up the idea in the 1960s, and it went through considerable changes before it emerged as the self-forging fragment.

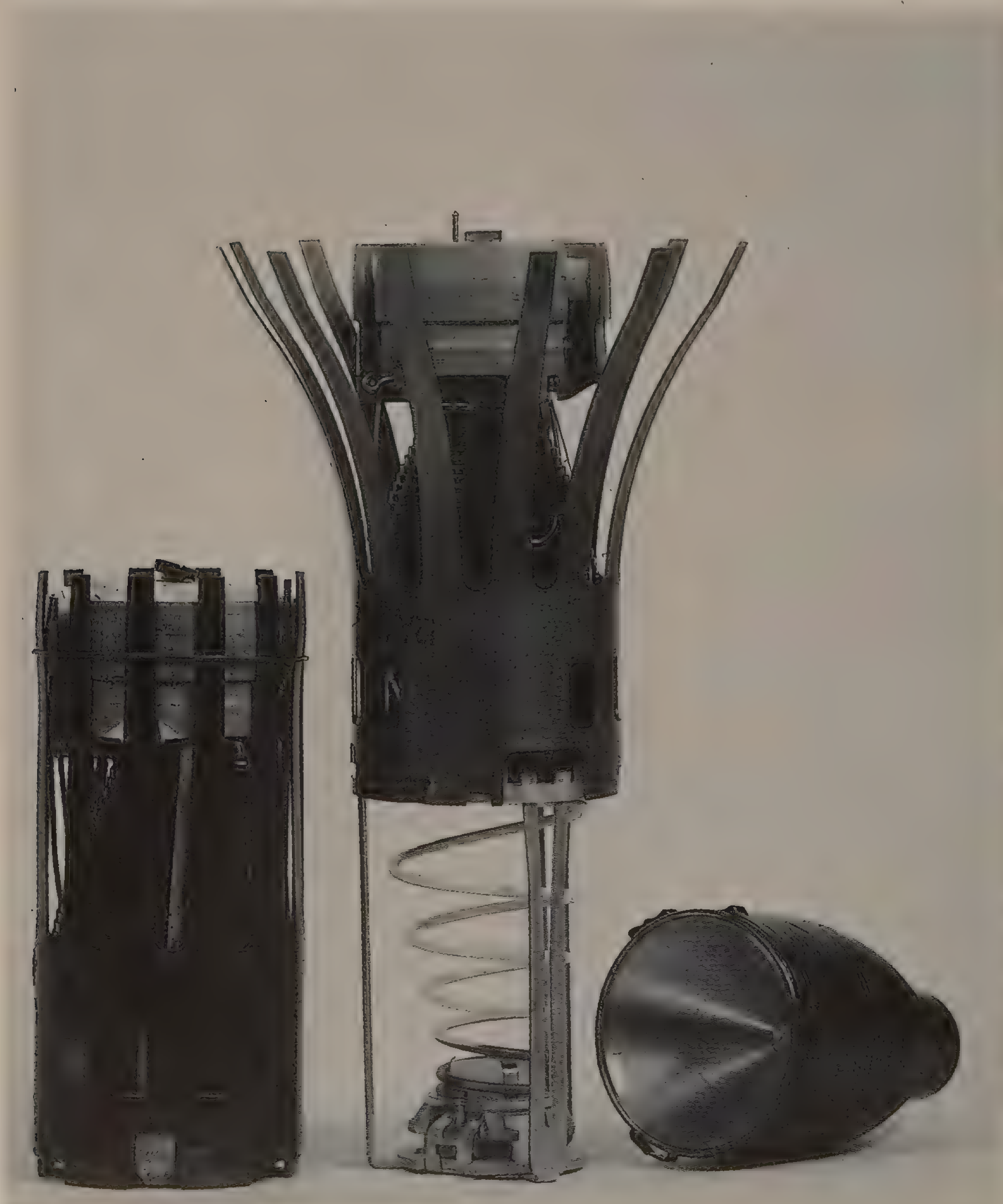
The principle is akin to that of the shaped charge except that instead of the usual steeply angled shaped-charge cone (or hemisphere) of thin metal, the thick plate which faces the target is a very shallow cone. When the explosive packed behind it detonates, this coned plate is blown off and the deforms into a heavy metal slug which is propelled at very high velocity and is capable of penetrating considerable thicknesses of armour over a distance of several tens of metres.

Development of the 203mm SADARM projectile began in 1977. By 1985 live rounds had been tested, but in that year the US Army reorganized and moved its 8in howitzer regiments to corps level. This changed their tactical role and in 1986 a programme for a 155mm projectile was begun. It is hoped that this will be standardized in 1992 and issued for service in 1993. Similar development, in both calibres, is being carried out by Rheinmetall in Germany, their projectile being known as ZEPL, and by Bofors of Sweden, their 155mm round being called BONUS.

From delivering guided submunitions, it is but a short step to the concept of guiding the shell itself; this was begun several years ago with the American 'Copperhead' concept, a fin-stabilized guided projectile fired from a 155mm howitzer and guided to its target by laser reflections. In fact the guidance only takes place during the final leg of the trajectory; for most of

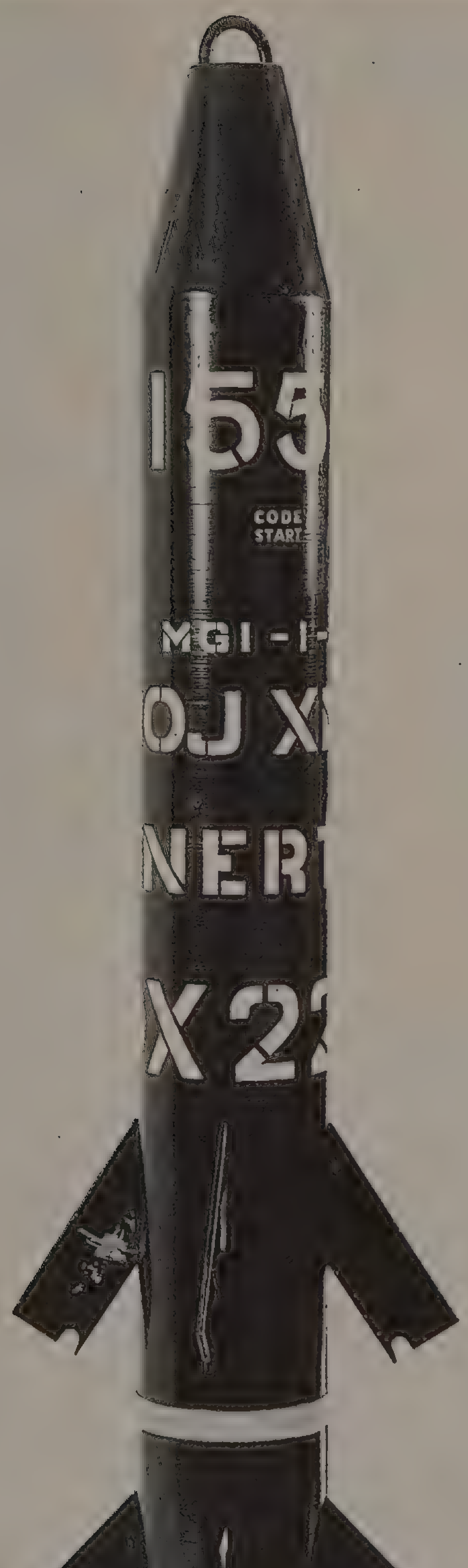
its flight Copperhead behaves like a conventional projectile. In the target area, there has to be a 'Laser Target Designator' which may be operated by a ground observer or from an aircraft or even a pilotless drone; but however it gets done, it is vital that somehow a laser beam be directed at the target. The reflection of this beam is detected by the incoming Copperhead, which then steers to impact on the source of reflection. The warhead is a shaped charge and Copperhead can destroy a main battle tank quite efficiently.

Copperhead has had a varied career; initial development began in 1971 in response to a US Army demand based upon their study of US Air Force laser-homing bombs in Vietnam. Initial production got off to a limping start in 1978 and was severely hampered by erratic Congressional support, difficulties in production, and fluctuating US Army requirements. One week they wanted 130,000, the following week the demand had dropped to 44,000, and in late 1982 the Army decided to scrap the entire programme. By this



◄ A typical bomblet used with Improved Conventional Munitions, showing the shaped charge and also one of the several methods of stabilizing the fall so as to deliver the charge accurately against its target.

► Copperhead, the laser-guided artillery projectile. After firing, the wings fold out so that it can steer towards the laser energy reflected from the target during the last phase of the trajectory.



time the British Army was contemplating adoption of Copperhead, but the production rounds were giving trouble in both US and UK tests, and it was this which drove the US Army to cancellation. However, wiser heads prevailed, production improvements meant better results on tests, and in 1983 the programme was reinstated, this time with a demand for 30,000 rounds, increased shortly afterwards to 100,000. Currently, work is in progress on Copperhead II, which suggests that Copperhead I has justified its existence; it now has an improved warhead which can, according to the makers, defeat reactive armour by using kinetic energy to overcome the reactive explosive layer before detonating the shaped charge. Copperhead II will, we are told, be a 'Fire and Forget' projectile, which suggests some form of active homing, no longer requiring some unsung hero to sit tight on the battlefield and keep his Laser Target Designator pointed in the right direction; this should make the device a somewhat more practical weapon, for it was this demand for a laser designator that eventually led the British Army to abandon their plans to adopt Copperhead.

The most recent proposal in this field is STAFF – Smart, Target Activated, Fire and Forget. It is currently envisaged as a 105mm projectile for direct fire against a tank and is intended to pass over the top of the tank, when a millimetric wave radar will detect the presence of the tank and fire a self-forging fragment downwards to penetrate the tank's upper surface. It is not anticipated that this will be in hardware form much before 1994.

Other current proposals for guided artillery projectiles include CHAMP and CGSP. CHAMP stands for Canard Homing Artillery Modular Projectile (and sounds like another case of inventing the acronym first and then bending the terminology to suit) and was born in the mid-1970s under US Naval sponsorship. The idea was to develop some form of add-on steering and guidance which would allow the conversion of conventional 'iron' projectiles into guided ones. It consisted of a sensor and guidance system fitting into the fuze well and with small canard wings alongside the ogive. The US Navy successfully demonstrated prototypes in 5in calibre, but in 1975 more or less gave the idea to the US Army which has since kept the idea afloat though with minimal expenditure. It is currently moving on low priority, and current work is understood to be concerned with deciding what sort of sensor should be developed.

◄
A West German terminally guided artillery projectile homing in on its target.

►
Another West German projectile delivering a self-forging fragment against a tank target.

CGSP stands for Conventional Geometry Smart Projectile and was begun in 1982 with the aim of finding a Fire and Forget successor to Copperhead. Two systems are currently under investigation; one, by Honeywell, uses a fluidic jet reaction system for control, a ring laser gyroscope for reference signals, and a millimetric wave-seeker. The other, by Raytheon, proposes an unusual 'Spin-Stabilized Guided Projectile' control system which uses explosive strips for a non-aerodynamic flight control. Target detection is currently performed by a two-colour infra-red seeker, but modular construction implies that other types of seeker could be 'plugged in' if preferred. It is doubtful if this projectile will reach operational status before the late 1990s.

All these systems rely upon the projectile having some form of seeking and guidance apparatus and thus becoming a free agent once it has discovered a target. An alternative approach, currently being explored in the US and in a British-Italian combined venture, is to equip the projectile with control and steering equipment, but direct it from the gun position. This can only be done, of course, when the gun position has an accurate picture of the target and accurate fixes of both the target and the projectile, so that the one can be steered to the other, a proviso which, with existing technology, restricts its application to fire against aerial targets. The technology was explored first by Ford Aerospace, with a directed 40mm projectile, but the most recent application, which is scheduled for production in late 1991, is the Course-Corrected Shell developed by OTO-Melara in co-operation with British Aerospace for use in 76mm naval guns against anti-ship missiles. As the target manoeuvres, it is tracked by radar and its position constantly updated. At the same time the computer calculates the position of the fired shell, basing this upon the known ballistic characteristics of the gun. The two positions are compared and course corrections for the shell are calculated and transmitted by radio link. The shell's trajectory is then changed by using five pyrotechnic pulse jets spaced around its centre of gravity, the pulses being fired in sequence to provide the appropriate lateral impulse. Although fired from a rifled gun, the shell has a slipping driving band so that its rate of spin is no more than about 200 revolutions per minute, simplifying the lateral correction problem. Four folding fins spring out after ejection from the gun muzzle and maintain the spin rate. The trajectory can be modified by about 15°, and the shell is fitted with a proximity fuze which will function when within lethal distance of the target. As presently configured the 76mm shell weighs 6.66kg and has a payload of 500g of high explosive and 1.1kg of tungsten cubes acting as pre-formed fragments.

Propelling Charges

Compared to the amount of work that has been done on projectiles over the past two decades, propelling charges have virtually stood still. Indeed, the only innovation in the past forty years has been the general adoption of combustible cartridge cases.

The combustible cartridge case began to make its appearance in the late 1960s to replace the cloth bagged charge. Instead of the traditional cotton- or wool-derived cloths used with charge bags, the combustible case uses a rigid cylinder of impregnated cellulose material enclosing the propellant grains. The gunpowder igniter is still present, though now concealed inside the combustible end of the case. The advantages are that there is now no possibility of leaving a smouldering residue in the chamber to ignite the new charge as it is being loaded; the waterproofing of the charge is far better; the ballistic performance is more regular, since the case can be calculated as part of the propelling charge and its combustion effect taken into account, rather than being a variable as was the case with the erratic combustion of cloth bags; and the entire cartridge is sufficiently rigid and robust to facilitate easier handling and allow it to be used as an intermediary between a rammer and the projectile in some forms of mechanical loading.

This latter feature, of which much is often made, is really a reaction to the sloppy nature of bagged charges filled haphazardly with granular propellant. In the days when cordite was the standard propellant for British guns the cartridges were every bit as rigid and easy to handle as a present-day combustible; but that only applied to cordite, and when the British Army went off the cordite standard, it realized that the awkward and uncontrollable squashy bags of granular propellant that it had learned to detest when using American ammunition were going to be the order of the day unless something better were found. Hence the combustible case, one suspects.

There was, though, rather more to it than that, as the other tabulated advantages show; but had cordite, or a

similar rigid propellant, been continued in service there would probably have been less urgency over developing the combustible case.

One of the current aims of cartridge designers is the 'modular charge', which, in some ways, smacks of re-inventing the wheel. The current types of 155mm howitzer propelling charge, particularly those standardized within NATO, involve an eight-zone system which is arrived at by combining bags of various weights and sizes of propellant. In many cases propellant is thrown away, to be destroyed later, when the need for a reduced charge involves stripping some of the bags from the cartridge. A Modular System is based on the idea of having the eight zones represented by eight equal-weight and equal-size bags of similar propellant, so that a reduced charge is still achieved by firing, say, five bags rather than eight, but the three bags left over can still be used at a later time by combining them with bags from another charge. Thus if ten rounds are fired at Charge Five, thirty bags are left over, making six more Charge Fives; no waste.

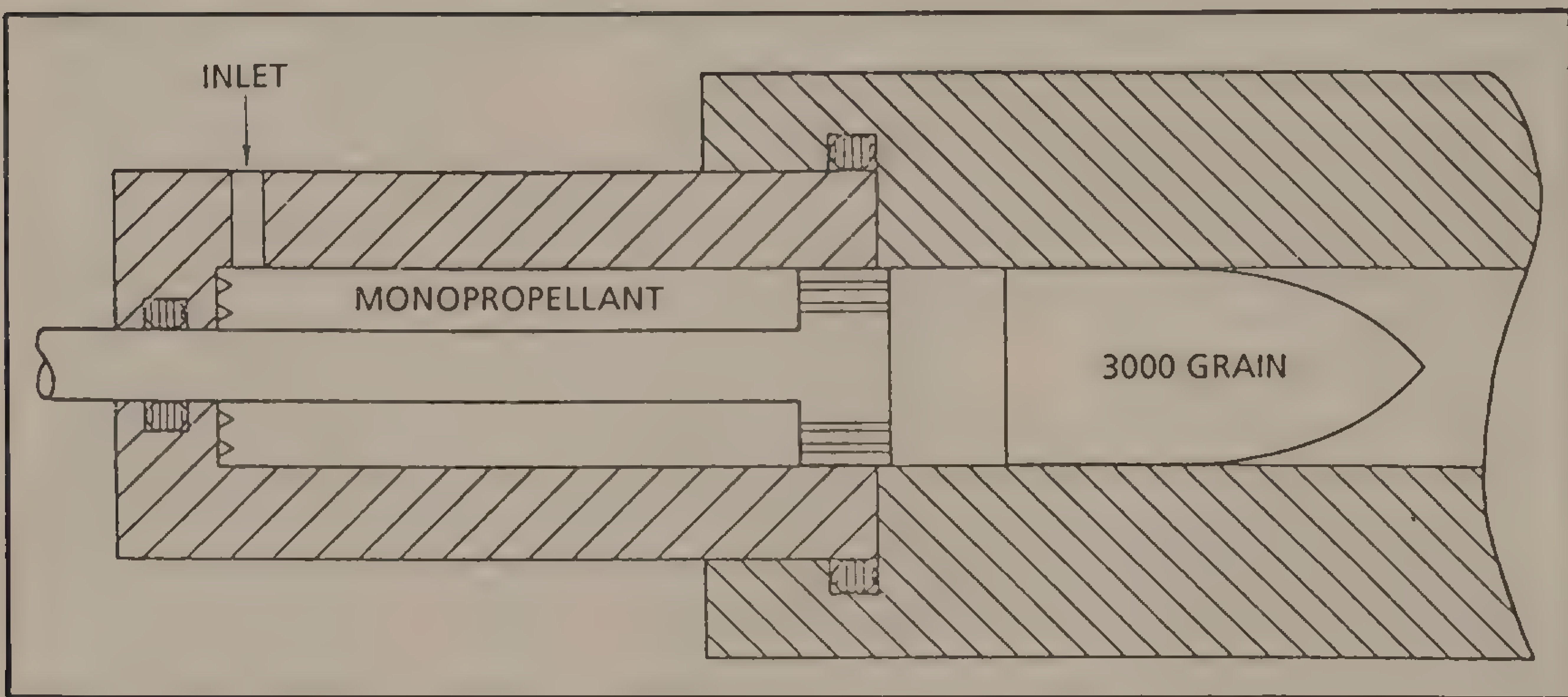
There is nothing new in the idea of modular charges *per se*; to quote but one example, the US 16in coast defence guns of the 1940s used an 832lb charge divided into eight equal sections. When firing at warships the full charge was employed, but for practice the charge could be reduced by removing bags, which could then be combined to make further reduced charges. Similar examples could be quoted for several American, British and other weapons. But – and this is the significant point – these were all *guns*. They required but one service charge – the maximum; anything else was a reduced practice charge, and in either case it was direct shooting. What we are now confronted with is the search for a modular charge for a *howitzer*, in which a variety of charge zones are required so as to give various trajectory options to suit various tactical requirements. The charges must be calculated so that they give a continuous coverage from minimum to maximum range with a certain degree (usually 15–20 per cent of range) of overlap between successive charges to avoid blind spots under certain conditions of terrain.

Hitherto this has been achieved by varying the weights and the propellant sizes in the different bags, which means very precise rules about which bags go with which to provide what charge. However, the NATO armies are now collaborating closely on this matter and it seems to be generally agreed that a modular system capable of giving 4,000 to 30,000 metres' range coverage with 10 per cent overlap between eight charges would be a satisfactory solution. One difficulty is that while a modular charge system can be developed to suit one particular shell, NATO interchangeability demands that their howitzers be able to fire the FH-70, US M107 and US M483 families of projectile, all of which currently demand their own charges and are unlikely to respond in the same way to any one charge system. Rheinmetall of Germany has developed a modular system which works well in the German FH-70R howitzer, though it is not stated which projectile is being used and there are some significant differences between the FH-70R and other NATO 155mm howitzers. A British proposal features six zones covering the 4,000–23,000 metres bracket with an additional Charge 7 to reach the maximum 30,000 metres' range, which is not a completely modular solution but certainly one which suggests a practical answer. It is likely to be some time before this particular nut is cracked to everyone's satisfaction.

The adoption of granular propellant was hastened by the need to find propellants that were less violently erosive than cordite, which had a high proportion of nitro-glycerine and hence a flame temperature rather too close to the melting point of steel. Moreover the granular form gave the ballisticians better control over the burning characteristics of the propellant, something which was desirable with the new types of projectile that were under development.

However, the chemists are always anxious to improve things, and while granular propellant is still, basically, the same nitro-cellulose that has been used for most of the century, there has never been a shortage of people anxious to try and develop some propellant that will generate more power in less bulk and with less wear on the gun.

Liquid propellant is a goal that has been earnestly pursued for upwards of forty years, and does not seem to be very much closer now than it was then. Research indicates that there are two basic methods of employing liquid propellant: bulk loading, which means pumping the required amount of propellant into the gun chamber and igniting it, or regenerative injection, which means injecting the propellant into the chamber during the actual combustion process. Early experiments aimed at bulk loading of some simple fuel, such as gasolene, and igniting it electrically; this was then overtaken by the idea of using hypergolic fuels, two separately stored and loaded liquids which, when they met in the gun



◄ The Regenerative Liquid Propellant system. A small quantity of propellant is leaked to the front of the piston and ignited; the resulting pressure forces the piston backward, causing more propellant to be sprayed into the combustion area behind the projectile. As the pressure increases, so does the quantity of propellant injected.

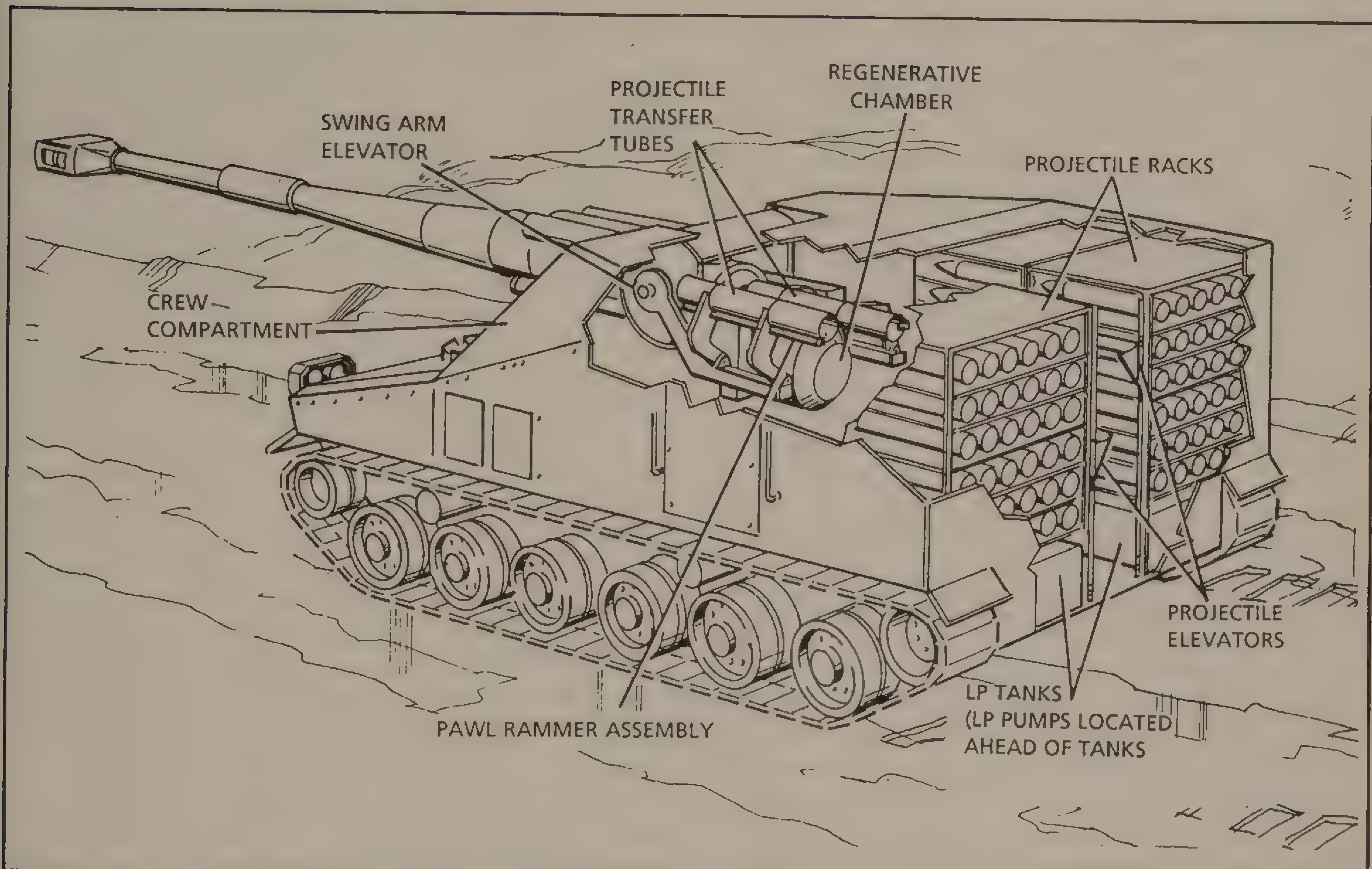
► One proposal for a self-propelled howitzer using liquid propellant.

chamber, reacted spontaneously to explode and propel the shell. This system means safer carriage of the fuels, since each is relatively harmless by itself. Current experimental work in the USA involves the use of triethanol ammonium nitrate and hydroxyl ammonium nitrate as the two components.

The underlying problem with bulk loading is that of regular ignition of the propellant mass. Once initial ignition has taken place, the hot gases of combustion penetrate the remaining liquid propellant, breaking it up in a random manner so that the 'surfaces' exposed to ignition will vary enormously from shot to shot. This varying combustion surface results in gas generation rates that are unpredictable and which therefore result in varying muzzle velocities and chamber pressures, some of which can be so high as to be dangerous. By comparison, conventional solid propellants present regular surfaces which ignite in a predictable manner and thus deliver regular and forecastable values. This problem is gradually being mastered, but perfection appears to be some distance away.

Regenerative injection, a more recent proposal, has the advantage that the system can be automatically controlled to inject and continue injection after combustion has commenced until the chamber pressure has reached the desired value, whereupon injection is cut off. This promises more accurate determination of velocity, a flexible system of charge zones and maximum economy of fuel. Perhaps the simplest form, and the most easily understandable, is that in which a floating piston is employed inside the gun chamber. The piston head has regulated holes in it; behind the piston is the charge of liquid propellant, in front of it is the combustion area of the gun chamber. An igniter on the front of the piston provides the initial gas pressure in the chamber, and this starts the piston moving rearward, putting pressure upon the liquid propellant held behind it. This pressure causes the propellant to be squirted through the holes and into the combustion chamber, where it ignites. Due to the design of the injection holes, the propellant is finely atomised and therefore ignites regularly and immediately, giving a predictable rate of burning. The burning of the injected fuel raises the pressure in the chamber, the piston moves back under this greater pressure, and more propellant is injected at higher pressure. This ignites and increases pressure, and so the cycle continues; the higher the pressure in the chamber caused by the burning, the higher the pressure on the piston and the higher the injection pressure, a process which continues until all the propellant has been consumed. Desirable ballistic characteristics can be achieved by varying the injection hole area or the piston stroke, or both, or by adding a small solid propellant booster to the igniter in order to step up the initial pressure and piston velocity.

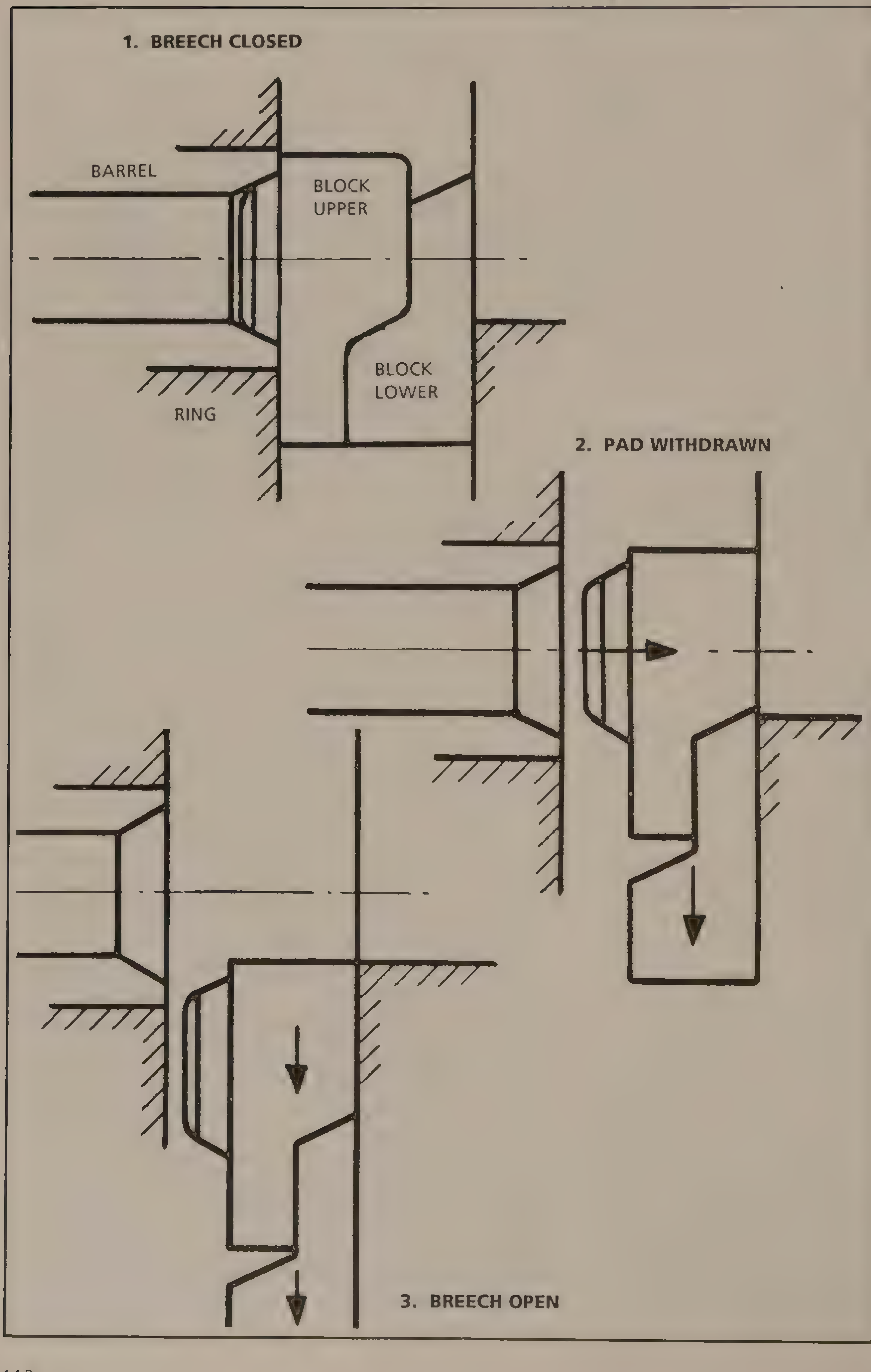
Advantages that accrue from the adoption of liquid fuel are: first, better control of the internal ballistics of the gun, and secondly, the possibility of designing smaller weapons. In the current M109A2 155mm howitzer, for example, the 32 propelling charges that are carried take up most of the available space inside the vehicle, constitute a hazard in action since they are in the same compartment as the crew, and demand one man to manipulate and load them. Moreover the containers in which the charges are packed weigh the same amount as the charges they contain, which is really surplus weight.



The same amount of propelling power in liquid form could be contained in a 200-litre drum – the familiar 'forty-gallon oil drum' – which could be located outside the crew compartment. Automatic injection into the gun would mean that the crewman would no longer be required, and because these fuels are difficult, if not impossible, to ignite at ambient pressures, the fire hazard from enemy projectiles would be negligible. Other advantages currently being touted are that adoption of liquid propellant would be a relatively simple add-on to present self-propelled weapons; that the use of liquid propellant would virtually eliminate muzzle flash and much smoke; and there would be no toxic fumes left in the bore. Perhaps the clinching argument is cost; current conventional charges average about $20 per kilogram; liquid fuel would be about one-tenth of that price. The US Ballistic Research Laboratory at Aberdeen Proving Ground recently calculated that had it been possible for the US Army to adopt liquid propellant in 1982 it would, by now, have saved $1,200 million.

An interesting variant on the liquid propellant theme is the 'Combustion Augmented Plasma' (CAP) gun system proposed by the FMC Corporation in the USA. This has, so far, only been publicized in somewhat general terms, but it involves liquid propellants packed into a conventional cartridge arrangement and then mixed and ignited by a powerful electric pulse. The subsequent reaction expels the projectile at very high velocity (up to 3,000 m/sec) and yet manages to cool and lubricate the gun bore in the process. It is claimed that by regulation of the electrical discharge it is possible to control the combustion rate and chamber pressure, thus allowing control of ballistics to permit, for example, low-velocity firing of guided projectiles. The system has been successfully tested in calibres up to 105mm, and development is continuing with the intention of producing a working 155mm system for test firing in 1991.

Ignition of the contemporary conventional propellant charge is a subject that has been neglected in the past, but is now being given some thought. Ever since the



◄ The 'split block' breech mechanism; when closed the rear block supports the front block and forces the obturating pad into the chamber. On opening, the rear block slides down to permit the front block to be withdrawn axially, before both blocks slide to the completely open position.

19th century the obvious methods of igniting charges – by a primer screwed or pressed into the base of the cartridge case, or one inserted into the vent of a bag-charge gun, either being initiated by electrical impulse or a percussion blow – have been accepted as standard, and there have been very few attempts to introduce anything new. So far as the cased charge goes there seems little probability of change, since the system is perfectly adequate and reliable. With bag-charge weapons the first demand for improvement came with the adoption of this system of cartridge for tank guns which demand a high rate of fire. The old method of having a hand-operated lock, opening it, ejecting the spent primer, inserting a new primer, closing the lock and cocking it, was far too slow and this led to the development of self-cocking locks with primer magazines, and automatic reloading every time the breech was opened and closed. And by relieving the loader of the additional task of operating the lock it also reduced the operation of the gun to much the same routine as that obtained with cased-charge weapons.

The same apparatus was the obvious choice for the new generation of field artillery weapons that embraced the burst-fire concept. The speed of loading and firing demanded by this was well up to tank standard and was being performed with far heavier ammunition and over a wide range of elevations, so that doing away with hand operation of the firing lock became imperative.

The only drawback with this system, particularly when applied to field artillery pieces, was the poor reliability of the early designs; they would fire the primer well enough, but the reloading was prone to jamming. This has since been improved, but in the middle 1970s the mechanical tube loader and magazine was giving sufficient problems to encourage people to look elsewhere, and among them were the designers of the new French 155m howitzer which was to be incorporated into the GCT self-propelled equipment. In this design the howitzer lived in its own section of the turret, fed by automated mechanisms and not easily accessible by the vehicle's crew; it is difficult enough to get at the breech for routine cleaning and maintenance, and the thought of trying to do it when the howitzer was loaded, in order to wrestle with a jammed tube magazine, was not a welcome one.

The French designers therefore resurrected an idea which had been briefly tried in Germany during the war, the use of induced electric current to fire the cartridge. The breech-block of the gun carries an electric induction coil, and a smaller coil is installed in series with an electric igniter in the base of the combustible cartridge. When the gun is loaded, and the breech closed and locked, the two coils lie in such proximity that sending a burst of electric current through the breech-block coil will induce a current in the cartridge coil which is of sufficient strength to fire the electric igniter and thus explode the charge. The price to be paid for this efficiency is the incorporation of the coil and igniter system in the cartridge, but the minor expense of this (it is, in fact, a simple and inexpensive printed circuit) is more than compensated by the absence of firing locks and primers and a totally fault-free firing system.

It is astonishing that this system has not been adopted elsewhere; one can understand reluctance to adapt an existing weapon, since this would involve expensive modifications to a large stock of ammunition, but there is no such restraint upon adopting the system for a totally new weapon and ammunition system, as did the French, and a number of these have seen the light of day since the French howitzer arrived.

More recently the British Ministry of Defence Royal Armament Research & Development Establishment (RARDE), working with a subcontractor, NEI International Research & Development, have proposed a laser-operated cartridge-ignition system. This involves using a pulsed Neodymium laser and directing the energy down a fibre-optic cable to a 90° beam deflector mounted on the side of the breech ring. From here the laser pulse is directed through the breech ring and block to another 90° deflector which directs the beam through a transparent pressure window in the face of the breech-block or vent bolt and thus into the gun chamber. One of the interesting advantages of this system is that it can only work when the breech is closed, since at all other times the fibre-optic channels in the breech ring and breech block are out of alignment, thus giving the system an automatic safety which, in other systems, often demands some involved engineering to achieve.

The system certainly works; it has completed firing trials in a 120mm tank gun, and a technology demonstrator in 155mm calibre is in the course of construction. At first glance it seems a somewhat involved method of ignition, but upon closer examination it is a lot simpler than it looks and it has a distinct edge in reliability over conventional primer systems.

Artillery fire control basically rests upon knowledge of where the gun is, knowledge of where the target is, calculation of the azimuth and distance between these two points, and conversion of that information into a range and azimuth which can be used by the gun. This is 'map data', so-called because it simply reflects information that can be culled from a map, translated into gun terms. A shell fired on this data would doubtless land somewhere near the target, and where there is observation of the target area and no particular requirement for absolute precision with the first shot, an opening shot can be fired 'off the map' and subsequently corrected on to the target. Indeed, probably 90 per cent of Second World War artillery fire was conducted in this manner, and given a moderate degree of skill on the part of the observer, the results are perfectly satisfactory.

Where a greater degree of precision is required, however, the map data must be modified in order to compensate for all the various forces which conspire to move the shell off the map trajectory and on to one which reflects the facts of life: wind, air density and temperature, the temperature of the propellant, the degree of wear of the gun, the curvature of the earth, the difference in height between gun and target. All these and other factors need to be taken into account and their individual effects calculated and balanced, one against the other, to produce a final 'correction of the moment', so-called because it refers to this particular shot at this particular time. The answers obtained will not necessarily be valid for another shot at the same target in half-an-hour's time, or even for a shot at a totally different target at the same time.

Like everything else, the calculation has to be something of a compromise. It is not possible to measure the various physical conditions throughout the shell's trajectory, nor is it possible to measure them at the precise moment they are needed. All that can be done is to determine at regular intervals the meteorological constants, at some spot not too far from the gun and make allowances, based upon experience and trials, for the change of data in the period before the next set of measurements. This can demand some considerable acts of faith; in Korea, during the winter of 1952, the meteor corrections changed with astonishing rapidity at sundown as the temperature fell. Whereas during the day the difference between map range and gun range might have been +400 yards – in other words, to hit a target 5,400 yards away on the map you would need to put 5,800 yards on the gun's sight – one hour after sunset it could easily be +1,200. But since the meteor information appeared at four-hour intervals, command post staffs had to use the 1600hrs figure until 2000hrs produced some new ones, and their corrections during the rapidly-changing four-hour period were derived largely from guesswork, tempered by practical experience. When supporting fire was called for during that four hours, the calculations included a fairly liberal 'plus' element to ensure that the shells didn't fall too close to one's own infantry due to the changing conditions.

At that time, of course, all the necessary calculation was performed by slide-rule, pencil and an assortment of graphical tables, and a certain amount of fudging, averaging and rounding-off crept into the equations. Over the years a number of mechanical-graphical plotting machines were invented, tried, briefly enthused over and then forgotten, for most of them lacked that vital element of self-instruction; with a slide-rule and a paper graph one could see what was happening at every stage, but mechanical calculators had to be operated by rote, and unless they were used daily, the rote was soon forgotten.

The other element of fire control, which is the foundation upon which all else is constructed, is the initial fixing of the gun and target positions. This relied upon survey being initiated by the Royal Engineers and brought forward to surveyed points – points of which the map coordinates were very accurately determined and from which a highly accurate azimuth to some visible feature was recorded – and then carried further forward by Royal Artillery surveyors who marked surveyed 'bearing pickets' in close proximity to the guns. From here the gun position personnel determined the position of their pivot gun – the right-hand gun of the troop or battery – which was the locus from which all map data was derived. In spite of this division of responsibility the accuracy was of a very high standard – civilian surveyors inducted into the Royal Artillery by conscription were astonished at the degree of accuracy demanded – and thus the fire control foundation was well laid. Azimuth was originated either from a high-level survey grid – the Ordnance Survey in UK, equivalent surveys elsewhere – or by astronomical observation. An 'Azimuth by Hour Angle' from the sun was generally considered to be accurate to 10 minutes of arc and as good as you were likely to get.

It follows from this brief description of fire control

FIRE CONTROL

▶ Modern gunlaying; laying the FH-70 howitzer using the Marconi 'Quickfire' data transmission system, the terminal for which is in the foreground.

as it stood in the 1950s that while there was no lack of willingness to try, the degree of accuracy of predicted fire – fire opened against a target based upon map data corrected as far as possible for all known conditions, in the hope of hitting the target without further adjustment – was a variable proposition. Sometimes it worked, and sometimes it didn't and when it didn't there was really no way of pinpointing where the error lay.

In 1961 the Royal Artillery received its first computer. It was made by Elliott, occupied a caravan some twenty feet long, demanded the services of a 27kVA generator, and had to be fed its instructions by punched paper tape. On a good day it could perform roughly the same level of computation as a present-day pocket calculator, but took far longer over it. After three weeks of perspiration we managed to make it perform a routine bearing-and-distance calculation (gun to target) and regarded it as rather like the Oracle at Delphi. Computing had Arrived.

The first field artillery computer to go into service was the US Army's FADAC (Field Artillery Digital Automatic Computer), which appeared in the late 1960s. What might be called a 'first generation' instrument, it consisted of a computer, a test set and a program input unit; there was an output port for a teleprinter, but in practical use the output was in the form of a digital display. FADAC could be used to compute firing data from target coordinates for up to five different batteries. It could also perform simple survey routines, calculate meteorological corrections to gun data, reduce fired data to map data for record purposes, produce gun programmes and deduce gun locations from sound-ranging information. Not all this ability was instantly available; the programs for various problems were kept on tape and had to be fed into the computer via the program input unit, and it was often necessary to reformat the keyboard so as to change the function of some of the keys. Nevertheless, FADAC was a considerable advance on the slide-rule and graphical firing table system, and it showed just how useful the electronic computer could be; and how accurate – the approximations and rounding-off days were over, since the computer could routinely handle the calculations to whatever degree of accuracy was considered necessary.

Hard on FADAC's heels the British Army adopted FACE (Field Artillery Computing Equipment). Built round the Marconi-Elliott 920B computer, it was generally similar to FADAC in its scope, being able to

◀ The SEDA field artillery computer, used by the Italian Army. (Officine Galileo)

handle calculations for three 8-gun batteries, deal with any service type of gun or rocket, produce meteor corrections, perform survey tasks and record targets. As with FADAC it had to be re-programmed for some of this, but this was easily done in the field by using a slip-in cassette system. FACE was later modified to allow output of information in digital form which could be sent to individual guns by AWDATS (Artillery Weapon Data Transmission System) and displayed at the gun on a small data panel.

During the 1970s more computers came into use. The German Army introduced 'Falke', based on a Telefunken TR-8 digital computer; the Norwegians introduced 'Odin' and the Swedes the Saab Ace and 9FA-101 models. By the middle 1970s the adoption of solid-state devices led to smaller computers which required less space and less power but withal could handle even more information than the 'first generation' models. One of the first of these was 'David', developed for the Israeli Defence Force between 1973 and 1977. This could compute data for up to six batteries, handle 28 stored targets or alternate gun positions and store up to 20 types of correction.

At this point we must add a third element into the fire control picture: *communication*. No element of the artillery exists in a vacuum; each element needs to converse with others in order to receive information – target location, meteorology, survey data – and to disseminate information – target nature, ammunition expenditure, records of targets fired on – and hence there is a need for a very comprehensive communications network. Information is essential; the guns must know what the situation at the front is, where the enemy is, what sort of targets are appearing, and this information is also vital to the higher echelons. As a result the artillery has its own information and intelligence communication network superimposed across the division or corps and is frequently better-informed about what is going on in the battle than the rest of the formation.

Hitherto the principal restriction upon this system has been the physical constraints imposed by radio networks. Thus an artillery regiment would have a comprehensive radio net among its own batteries and forward observers, supply echelon and administration. It would also have a toehold upon the divisional radio net, and division HQ would have its own tentacle in the brigade or corps net. But to get information from the forward observer of F Troop, P Battery, X Regiment up to the Corps Commander Royal Artillery took some time since it had to be rebroadcast at each change of network, from regiment to division, division to brigade and brigade to corps. With the added hazard of filtering, editing and possible mangling on the way up the tree.

And so, finally, we arrive at the current thinking, of dedicated data transfer networks which link the entire artillery structure, from the highest commander in the theatre to the lowliest forward observer with an infantry section, and stretching sideways to take in anyone who has anything to offer – air reconnaissance, naval bombardment units, air defence . . . the list can be variously expanded to cater for whatever type of operation is in view. And stemming from this the concept of two-level field artillery computing was developed; the divisional – or corps, or whatever level was selected – data transmission and computing system could handle much of the artillery regimental work, while more compact instruments could be provided for gun batteries to give them sufficient ability to cope with targets and data at their own level if they were required to operate independently of the command data processing network.

The first high-level system to be placed in service, in 1980, was the French ATILA, a fully-integrated data transmission and computing system which links the forward observer with the fire control computer at regimental HQ, which is the 'decision centre'. The information and fire-mission decisions are then sent down to the batteries and then to the individual guns. Should the regimental HQ be put out of action, an emergency net is built into the system to permit raw target data to be passed directly to the fire control computers at battery level or, for self-propelled howitzers, to the computers actually on the howitzers. The hourly capacity of the central processor is 300 messages in and 300 out. Real-time processing of fire-control information is carried out and up to 50 fire missions can be memorized, together with more than 50 gun positions. ATILA is also capable of performing fire control calculations for four batteries, each of which may have different types of weapon. Technically, the system is capable of a reaction time, from initial transmission of information to the firing data being displayed at the guns, of 35 seconds.

There are four radio nets overlaying this organization: the 'Fire Network' links the forward observers and surveillance radars with the computer; the 'Technical

Network' connects the battery command posts and the meteorological radar with the computer; the 'Gun Display Network' links each battery CP with its own six guns; and the 'Command Network' links the battery commanders with the regimental CP and the computer.

When a forward observer initiates a fire request, the data which he keys into his console is passed into the computer. The entry console displays the inserted data, allowing the observer to check and control it if necessary, after which he transmits it in a high-speed burst of digital data. The computer receives this fire request and applies various check processes; it sorts the various requests according to priorities laid down by higher command; thus, one observer in a particularly dangerous sector may have a higher priority accorded his requests than another observer in a quiet sector, and the computer will classify the requests accordingly. It will also sort requests according to target priority; tanks may be given 'priority one', and thus any request describing the target as tanks will be moved to the head of the list. The computer then displays the top three priority fire requests to the Fire Control Officer and leaves him the responsibility of evaluating which is the most urgent, or parcelling all three out to batteries. At the same time the computer will work out and display such decision-making aids as what guns are actually available, what Charge Zone is required, what the ammunition stock position is, whether other targets in the same area have been fired on and whether a simple adjustment from one of them will produce the required data, or whether the target is too close to friendly troops. Having taken all this into account the Fire Control Officer instructs the computer. It then works out firing data for the specified battery and transmits this to the battery CP, from where it is sent to the guns. Assuming that the correct data was inserted by the observer in the first place, the opening rounds should fall within 50–100 metres of the target, and the observer's subsequent correction can be processed and presented on the gun data displays in a few seconds. After the mission is completed, the battery reports back its ammunition expenditure and relevant gun details, and the target information is stored in the computer ready for re-engagement.

The British Army spent some years in careful assessment of the impact of computing on artillery control before it took the next step, and in 1978 it announced the development of BATES – the Battlefield Artillery Target Engagement System. This takes the same route as ATILA but goes considerably farther by incorporating not only the fundamental artillery computing ability but adding facilities that will allow tactical information to be included, permit co-ordination with close air support and infantry mortars for fire planning, and so become a broadbased artillery command network as well as a functional computing system. Expected to enter service in 1990 it will replace FACE, AWDATS and AMETS (the Artillery Meteorological System) and comprises a network of more than 800 cells deployed at all levels from forward observers and individual fire units up to divisional and corps artillery headquarters. It will be configured in various ways, from hand-held units up to vehicle installations. Each cell will have a computer and one or more display devices, and a small number of basic hardware components are arranged into appropriate configurations to make four cell types. Processing cells, deployed at all major artillery command posts and headquarters from battery to corps HQ level, will handle the bulk of the data processing. Each such cell includes a computer, one or more video display units, a data recorder and program loader, printer, plotter and interfaces to trunk communications or combat radio nets. Major access cells, deployed with the artillery command and higher non-artillery commanders, act as remote stations to the processing cells. Minor access cells, deployed with individuals such as forward observers, provide facilities to compose, transmit, receive and display messages, being based on a small integral processing subsystem with built-in communication interfaces. Display cells, located at individual fire units, display fire orders and provide facilities to transmit status information.

The Bundeswehr is in the process of adopting 'Adler' (Artillerie Daten- Lage- und Einsatz-Rechnerverbund – Artillery Data, Situation and Operations Computing system) which allies a computer-based C^3I (Command, Communications, Control and Intelligence) system to the artillery computing function. All reconnaissance information and intelligence will flow into 'Heros', the C^3I system. The Adler system will then control the flow of information to and from higher artillery command and control systems. Associated with Adler is IFAB (Integrated Fire Control for Artillery Batteries) which will be fed with information from battlefield surveillance equipments and forward observers and will then determine firing data, produce fire orders, and relay information into the Adler system. IFAB will also be

able to perform all the survey routines necessary for location and orientation of guns, ARES (Artillery Rocket Operations System) will perform the same role for the rocket artillery batteries equipped with the 110mm Light Artillery Rocket System or the Multiple Launch Rocket System.

There are a number of other systems under development, but the examples given above will suffice to indicate the general approach to the command and control problem. Broadly, what is intended is to insert into the system every conceivable piece of information that might have bearing upon the tactical situation, then filter and process this so that commanders can be presented with what is important in their particular context, and overlay this upon the meat-and-potatoes computing function. In the opinion of some advocates of high-level systems, it cannot be long before artificial intelligence will be applied to the military decision-making process, and decisions, based upon parametric factors, will be presented to the commander by the computer. Unfortunately, computers only know what they are told, and the ability to leap from incomplete information to reasoned assumption to decision, inherent in the human brain, is not yet available in electronic form. Even when artificial intelligence is workable, it will take a long time before it overcomes the innate conservatism of the users; one observer has commented that it could take two generations, until today's schoolchildren, familiarized with computers from their earliest days, are senior military commanders prepared to accept a computer's decisions.

Just to show that there are other ways of approaching the artillery fire control problem, it would be well to mention 'Fieldguard', a Swiss system. Initially developed for use with rocket-launchers in the late 1970s, it was later modified to operate with conventional artillery. It consists of a radar, which tracks the projectile, linked to a computer programmed with ballistic information about the projectiles. One round of special 'pilot shell' is fired; this has the same ballistic performance as the service projectile but is designed to self-destruct at a point about three-quarters of the way along the trajectory. The radar tracks the shell and plots the trajectory to the self-destruction point, and then extrapolates from this data to predict the remaining part of the trajectory and the point of impact. If, as is probable, this extrapolated impact point is not on the target, a correction is deduced and applied to the gun, and a second pilot is fired. This is similarly tracked and the impact point deduced. If necessary, as many as six pilots can be fired and their mean point of impact calculated. Eventually the correct trajectory is determined and the effective projectile is fired, to land squarely on the target.

In the case of expensive rockets armed with submunitions the self-destruct mechanism is not employed, the rocket being allowed to complete its trajectory and do what damage it can before the firing data is modified to produce the next rocket in the correct spot. Alternatively, it is possible to fire the pilot rounds at some other target, at a known offset angle from the prime target, and then apply the deduced corrections to the prime target map data. Fieldguard is used by the Bundeswehr with their 100mm LAR rocket system and by a number of other, unspecified, countries with both rockets and tube artillery.

The Autonomous Gun

It has always been customary to group artillery into convenient units – 4-gun troops, 8-gun batteries or whatever – for convenience of control and for concentration of firepower. But concentrations of artillery invite concentrations of retaliatory fire, and the past few years have seen many attempts at dividing up the guns so as to make them into less attractive and profitable targets. But the ruling problem has been that of control. Years ago it was occasionally useful to detach a single gun and send it to a forward position in order to engage some particularly troublesome or difficult target not easily engaged from the normal battery location; the 'pistol gun' as it was called. While displacing a single gun and some ammunition was relatively easy, it was less easy to muster the necessary command, communications and fire-control personnel and equipment to accompany the gun, process its fire orders and provide its data. to put it bluntly, the normal establishment of men and equipment was never intended to cover this type of operation, and therefore the necessary staff and equipment had to be scraped up from here and there. It was this demand for command, control and communication which governed the size of a firing unit and more or less controlled the size of troops and batteries of artillery.

Now, however, as can be appreciated from the descriptions of ATILA and BATES given above, we are in a position to equip each gun with miniaturized

computers which will produce firing data prepared by a computer some considerable distance away and relayed by radio data transmission; all we need to know is where the gun is in relation to everything else on the battlefield and still maintain full control over them.

This aspect of full control should be emphasized, since without it only chaos can ensue. Almost ten years ago the French Army had equipped one of their new GCT 155mm self-propelled howitzers with a complete electronic array to make the weapon entirely autonomous; it had an inertial platform which gave its position at any time and determined the azimuth of the barrel; radio communication to provide contact with forward observers; and a fire control computer which, fed with target information from the forward observer, gun location from the inertial platform, and meteor information from the data transmission system, allowed the gun commander to calculate his own firing data to the target and carry out his own fire mission. The reaction of most seasoned artillerymen, myself included, was horror. Here, we thought, was independence gone mad, with individual guns roaming around the battlefield engaging targets when and where they felt like it without any semblance of higher control. And at that

The first autonomous towed gun; a Bofors FH-77B howitzer fitted with the Ferranti FIN 1150 navigation system (alongside the panoramic sight), allowing the gun's position and pointing to be determined without outside reference. Note also the electronic data receiver beneath the sight, and the two joysticks with which the layer controls elevation and traverse.

time we were probably right, had the French been silly enough to try it.

What we overlooked was the promise of ATILA and similar systems, then still in the pipe-line and not entirely comprehended outside the laboratories in which they were being perfected. What we failed to see was the ability of these systems to reach right down to the individual gun. So that the sequence of events now begins by the gun scuttling off to some private hide and then reporting its location, as determined by its inertial platform position and azimuth system, to the central computer. The forward observer similarly reports his potential target to the computer. The computer then, far faster than could be done by a human operator, assesses the positions of all the guns in its network, selects two or four, or whatever strength is necessary, that are in suitable locations and calculates the necessary firing data for them. This is then transmitted to the individual guns, together with the necessary fire orders, and all then engage the selected target. The effect at the target is no different from the effect that would have obtained had the guns been clustered together in the traditional troop or battery formation, but since they are actually dispersed several miles

▶ The Ferranti Position and Azimuth Determining System (PADS), used by the British and other armies, enables artillery to be precisely located very rapidly and without the need for external survey information.

apart, any meaningful retaliation is hampered before it begins.

The ability to engage targets on a one-to-one link with a forward observer, using the gun's own computer, is still there, but is constrained by the observance of a simple rule, that guns don't 'do their own thing' but can only engage when authorized to do so by their command post – which may well be miles away but which, nevertheless, is the tactical commander and retains operational authority over the gun's activity. If there is nothing more pressing, then yes F Troop forward observer can have his gun or guns and conduct a private shoot against an enemy observation tank which has suddenly appeared on his front. But if the battery command post knows that in a few minutes those guns are going to be required for something more important, then F Troop forward observer is refused his one-man show and might well be offered the services of two guns elsewhere in the network that are capable of carrying out what he wants, but are not involved in the higher priority activity. Thus there is autonomy, but there is also the overriding principle of command from the highest levels, made possible by data transmission systems and computers and, *inter alia*, conferring the utmost flexibility both in manoeuvre and in engagement that can be imagined.

Artillery Intelligence

The intelligence required by artillery is, fundamentally, the same as that required by any other arm; where is the enemy, in what strength, and what are his likely future moves? But while the artillery is generally interested in the enemy's order of battle, it is specifically interested in the order of battle of the enemy artillery so that, when the time comes, it can be directly attacked in order to neutralize its threat.

Among the weaknesses of armed forces is their hierarchical structure and their orderly organization. Given that the order of battle of an enemy force is known, identifying, say, an armoured division as being one's opponent, means that reference to the enemy's tables of organization will indicate that (for example) three self-propelled 203mm howitzer regiments are in the division. All that remains to be done is to find them, after which one can be moderately certain that all the enemy's artillery is targeted. This sounds too good to be true, and it is; there are such things as regiments attached and detached, additional gun strength from higher formations brought in for particular operations – any number of factors which can bedevil the simple order of battle. But, again, knowledge of an enemy's thought processes and military logic will frequently suggest the presence of these things.

To the more concrete problem of identifying and locating enemy artillery, there are more concrete methods of solution. One of the most reliable is Sound Ranging, using the inescapable noise of a gun firing to identify it and provide its location. Flash Spotting is less common today, since flashless propellants have more or less neutralized it, but this system is retained by some forces and can still play a part. Aerial observation, particularly allied to sensors such as infrared, television and colour-discriminating photography is also of great value.

Sound-Ranging

When a gun fires it propagates a sound wave which spreads out concentrically from the gun's position until, eventually, it dies away. A sensitive microphone can detect this sound wave at considerable distances from the gun. (It would be as well to make clear that 'microphone' in this context does not mean quite the same thing as it does in the context of, say, a telephone or radio; a sound-ranging microphone will not detect speech. It is a convenient, but slightly misleading, term for a device which detects the passage of the air disturbance caused by the sound wave. In its simplest form it is no more than a heated filament which, cooled momentarily by the movement of air, alters its electrical characteristics and thus changes a current flowing through it in a way that can be detected by some sensitive instrument.)

If a number of microphones are laid out in line, several hundreds of metres apart, and connected by either wire or radio to some central recording instrument, it is possible to detect the passage of a given sound wave across each microphone. The time difference between the appearance of the wave between any pair of microphones can be used to calculate the direction from which the wave came. Calculating this time difference for the various combinations of pairs that can be extracted from six microphones in a line produces a number of rays of direction which can be plotted on a map. These will come together at the

source of the sound wave, thus indicating the location of the gun which made the noise.

This, in essence, is sound-ranging. The nature of the recording instrument and the method of plotting the rays varies according to the technology available at the time. When sound-ranging began, during the First World War, the instrument was a string galvanometer in which six wires, each representing a microphone, were displaced by the microphone current and thus caused light to be reflected on to a photographic film. This had to be developed, after which the images could be read and calculation made, and the rays plotted on a large-scale map. In the Second World War an improved version of this was still in use, gradually replaced by an instrument with six 'pens' which delivered an electrical discharge to sensitive paper and 'burned' the vibrations of the needle into the paper as it passed the pens at regulated speed. Plotting was, again, graphical. Today the instrument is the ubiquitous computer which simply extracts the time intervals, performs the necessary calculations and produces a set of coordinates.

For some years in the 1960s, though, sound-ranging was almost extinct in most armies. These were the years when mobility and fluid warfare were the accepted thing, and at the same time the sound-ranging system was hampered by the need to lay miles of wire to link the microphones with the central recording instrument and also with observers in the front line. For it is obvious that the recorder cannot run constantly, since it would simply record every noise on the front without distinction. Forward observers must be deployed, and given control of the recording instrument; when they hear a gun fire, they press a switch and the recorder begins to run; after a sufficient interval to be sure the sound has passed every microphone, the observer switches the instrument off. In this way, it is hoped (and it is generally true) that only the particular gun sound the observer heard will register. Which means more wire from the forward observers to the recorder. A sound-ranging base could eat up wire and took several hours to deploy. And when the army moved on, it took several more hours to recover, since the wire was too scarce and valuable to be abandoned except under great pressure. (There was also the ever-present problem of other units, short of telephone wire, who regarded a sound-ranging base as manna from heaven.)

The obvious answer was radio, but this presented some enormous technical problems which need not be recounted here and which were not satisfactorily solved until the early 1970s. Once a satisfactory radio link system was available, sound-ranging came back into favour, since the system could now be much more rapidly deployed and re-deployed, fast enough to keep up with a moderately mobile war.

New technology is also being applied to sound-ranging in other ways; the West German Army, for example, has developed a system of grouping microphones in bunches of four, several bunches being spread across the sound-ranging base. The precise details of this system have not been made public, but it is claimed that greater accuracy and sensitivity results, and that accurate location up to 25–30 kilometres beyond the FEBA is possible.

Another aspect under study is the design of microphones capable of producing location data from the sound of rockets being launched. This is a totally different sound from that of a gun being fired, and consequently the standard microphones do not deliver a signal that can be successfully analysed.

Flash-Spotting

Flash-spotting is, in many ways, similar to sound-ranging in that it uses an unavoidable emanation to provide information. As originally used in the two great wars, the system used a number of observers in the front line who used optical instruments to detect flashes and report the azimuth and time of their occurrence. This information was then correlated at some central point, and flashes occurring at the same time were plotted to produce a position. The gradual introduction of flashless propellants during the Second World War was seen as the end of flash-spotting, but it lingered on for several years since the flashless propellants of the time were not, in fact, truly flashless, and they could very often be detected by skilled observers, particularly at night.

The other difficulty with flash-spotting, less significant prior to 1945 but of importance today, is that it is labour-intensive, requiring a considerable number of highly skilled operatives. So that with the reduction in manpower common to Western armies, and the gradual improvement of propellant powders, flash-spotting went into a decline in the 1960s; the returns were simply not worth the outlay.

What has now caused a change of opinion is the

development of highly efficient thermal-imaging systems. It is now within the bounds of possibility to use thermal imaging to detect the heat emanations from the gun muzzle; this is still flash-spotting, but using electro-optical means instead of optical. Little has been published on this subject, but it is known that the West German Army planned to replace its existing optical flash-spotting system with a thermal-imaging system by 1990.

Air Observation

Air observation for artillery purposes traditionally relied upon two sources; dedicated air force artillery reconnaissance flights, and artillery-owned air observation aircraft, manned by artillery officers. The former was concerned with aerial photography and the detection of targets, the latter with the engagement of targets by simply acting as a super-elevated observation post to control fire. Contrary to popular opinion, air observation post aircraft did not fly over the target; they merely flew high over their own lines in order to obtain visual command.

Both these systems have disappeared. Artillery reconnaissance flights by air force machines have been abandoned because air forces are too busy to bother with the petty requirements of the foot soldiery, and air observation posts are far too vulnerable in the face of modern anti-aircraft weapons. By 1960 artillery was turning to the promise of the RPV – Remotely Piloted Vehicle – or 'drone', an unmanned, remote-controlled miniature aircraft equipped with cameras, which could be flown across a potential target area to produce photographs which could then be studied to provide target information.

The first RPVs were made-over target drones equipped with two or three conventional cameras. They were winged aircraft, with small gasolene engines, with direct remote control from the ground and a parachute recovery system. Launched from a portable ramp by jet assistance, they were flown by a ground operator either by visual command or by radar tracking; the operator switched on the cameras when over the target area, made a number of passes, then flew the machine back to his location. Once there, the engine was cut and a parachute deployed to lower the machine to the ground where the film could be recovered and taken away for processing. Half an hour or so later, information was available and fire missions could be planned.

Very soon an attempt was made to incorporate automatic processing equipment so that the exposed film could be developed and fixed during the homeward leg of the flight and thus as soon as the machine landed the processed film would be available for interpretation. But before this system could be fully developed it had become obvious that the existing drone system was scarcely adequate and as early as 1959 work had begun on a far more modern system, the Canadair CL-89. This resembles a missile more than an aircraft, being a cylindrical body with cruciform fins. It is driven by a turbojet engine and has a speed of 740km/hr, far faster than the original type of drone. It is equipped either with conventional cameras or with infra-red linescan equipment, and instead of being controlled throughout its flight by a ground 'pilot', it is pre-programmed to follow a flight pattern calculated to take it across the target area and then return to its base. Recovery is assisted by the drone having a homing receiver working in conjunction with a radio beacon at the recovery point, so that any minor errors in the return flight, due to unexpected winds for example, will be corrected. Although the film still has to be processed on return, the faster speed of the CL-89 made this acceptable.

The CL-89 went into service with Britain, France, West Germany, Italy and Canada in the late 1960s and will probably remain in use throughout the remainder of the century. It is an efficient system and produces the information the artillery require and, most important of all, it lies entirely under the artillery's hands; it is no longer necessary to go cap in hand to other services in order to beg for the information. Moreover the drone system is an all-weather all-hours system; its only restriction lies in the physical problem of visibility; fog can upset optical reconnaissance, but darkness is no bar to operation since it carries flares to assist photography, and infra-red linescan can produce answers in practically any circumstances.

Since the first drones went into use in the 1960s many companies have produced designs for reconnaissance machines, but the market has proved curiously reluctant. Perhaps the greatest boost to the RPV's image was due to the Israeli employment of drones for battlefield artillery reconnaissance in the Bekaa Valley. The Israelis produce a number of simple but highly effective drones which carry television, conventional cameras and other types of sensor, and their successful employment in war soon convinced other countries of

their utility. The current research tendency appears to be towards the development of very fast machines which, by their speed, small size and agility can survive to reach their target and then transmit information directly back by radio, converting the visual images obtained by infra-red or television into digital information which can be translated back into visual images at the receiving end. Once the drone has transmitted its information it turns and runs for home, but its survival on the homeward leg is now of lesser importance.

Another tendency is towards adapting RPVs into actual weapons, giving them explosive warheads and equipping them with sensors which will either allow them to home on to specific targets or which will permit them to be guided by a ground controller. These, though, scarcely fall within the remit of 'reconnaissance', and the line between an expendable drone and a missile is a very fine one indeed.

One is inclined to ask what satellite reconnaissance can contribute to artillery intelligence, but the answer has to be 'very little'. In the first place, despite tales of reading car licence plates and newspapers from altitudes of 300 miles or more, the amount of decipherable detail suitable for artillery target recognition that can

▶ The Swiss Contraves Ranger, one of several designs of remotely piloted reconnaissance drones which can be used to acquire targets for artillery.

be extracted from the average satellite picture is relatively small. In the second place, the weather is more likely to be working against this system than with it; RPVs operate at heights between 300 metres and 1,500 metres above the ground, so that they are generally below any cloud cover. Analysis several years ago showed that, in central and western Europe, there is cloud for something like two-thirds of the time, sufficient to almost guarantee that when the need is greatest, the satellite will be blinded.

The other objection raised against RPVs is their vulnerability to anti-aircraft fire, but this is more apparant than real. They fly fast and low, therefore their angular displacement is rapid and tracking them with a hand-held missile or hand-operated short-range weapon is difficult. Moreover their size makes them an extremely deceptive target. A man seeing a winged machine flying through the air instinctively thinks of a full-sized aircraft and assumes a range accordingly. In fact he is looking at a one-third size aircraft at one-third the assumed range. By the time he has opened fire at his assumed target, missed, re-assessed it and re-aimed, the target is beyond his reach in most cases. Shooting at RPVs is not as easy as it looks, as several anti-aircraft gunners who have fired against target drones can testify.

Radar Location

During the closing weeks of the Second World War the British Army began experimenting with the use of radar to detect mortar bombs in flight and so arrive at their point of origin. Although cumbersome, the system worked and was gradually improved in the following years. The electronic revolution which followed the invention of the transistor led to the development of computer-equipped radars which automated the process and by the middle 1960s the detection of mortars by radar was a cut-and-dried procedure. Applying the technique to artillery was, however, not so easy.

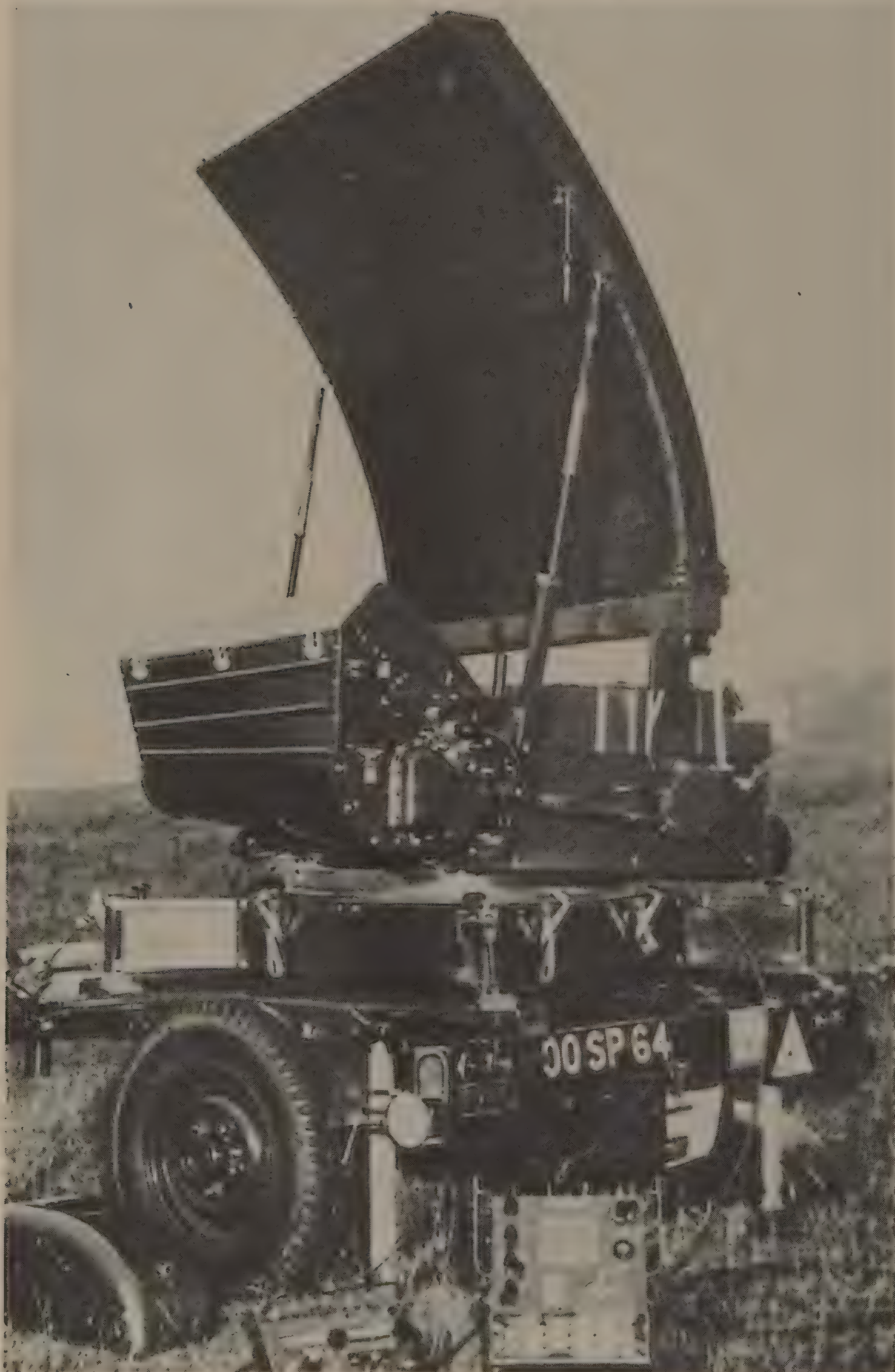
The mortar-detecting radar worked because of the unique ballistic characteristics of the mortar. The mortar bomb's trajectory is relatively stereotyped; a high, looping parabola which is fairly constant within certain limits. Given this, all that is necessary is for the radar to detect the bomb during the upward leg of its trajectory and fix it in time and space, storing this information in the computer. The radar then flips its antenna up and catches the bomb a second time, further up the trajectory, and fixes this point. The computer now calculates the path between the two points and then extrapolates backwards until the assumed trajectory intersects the assumed horizontal plane. Corrections are made to compensate for the actual height above sea level of the assumed mortar position, and a final location is deduced. The accuracy obtainable is in the order of 50 metres at 10,000 metres' range, quite sufficient to direct artillery fire on to the mortar before half-a-dozen bombs have been fired.

The first radars of this type appeared in the 1960s, typified by the British 'Green Archer' and American AN/MPQ-4. These, though still in use, have been generally replaced, the British now using 'Cymbeline' and the US Army the AN/TPQ-36. The 'flip-up' antenna has now been superseded by twin-beam antennæ which detect the bomb in their separate beams. In the TPQ-36 operation is entirely automatic, the radar scanning its sector and tracking anything it sees, computing the origin and supplying coordinates, generally before the offending projectile has hit the ground. It can also use separate track channels to track and compute several projectiles simultaneously.

Locating mortars is, by now, a routine operation. Locating artillery from the flight of its projectiles is, though, not so easy. Guns and more particularly howitzers, use various projectiles and various charges and thus have a multiplicity of trajectories that can cover the same range. Nevertheless, much work has gone into this field and the US Army deploy the AN/TPQ-37 Weapon Locating Radar which is specifically designed to counter artillery and rockets and which is claimed to be the only system having this capability anywhere in the world. Precisely how it manages to assess the correct trajectory of what it sees is not disclosed, but since the US Army has purchased 72 systems since it was first developed in 1977, it must work. Moreover, although restricted by a moratorium on technology transfer it has been sold to several Middle and Far Eastern countries at an average cost of $10 million per unit, and nobody is going to pay that sort of money for something that doesn't produce the answers.

Radar is also used in its usual role to watch the front and detect ground targets. These 'battlefield surveillance radars', exemplified by the British ZB298, American AN/PPS-5, Soviet PSNR-1, French RATAC and many others, are generally Doppler radars which distinguish moving targets and display their presence either on a simple range display or by audible tone.

▶
The French RB12 short-range battlefield surveillance radar with its remote control unit.



◄
Cymbeline, a mortar-locating radar in use with the British Army, also has the ability to track artillery projectiles and deduce their origin.

►
Night vision devices, such as this Pilkington 'Eagle' long-range viewer, give forward observers control of the battlefield at night.

►►
A Laser Target Designator combined with a laser rangefinder and an observing instrument, giving the forward observer all the facilities he requires to locate a target and then provide laser illumination to steer a Copperhead or similar projectile to impact.

With practise an operator can learn to distinguish between different targets, since their speed, plus secondary reflections from moving components, determines the frequency of the Doppler echo and so generates a distinctive tone or medley of tones. Thus a walking man generates a low-pitched tone, while a light vehicle moving at speed develops a high pitch. In the 1960s, when these radars first appeared, there was a good deal of merriment in the popular Press over the claim that they could distinguish between men and women walking, due to the different movement of their hips producing secondary tones, and there was some truth in this. A skilled listener soon learns to distinguish between wheeled vehicles and tracked ones, between a single man and three of four men, between heavy trucks and light ones, and this type of light and portable radar is now standard in most artillery observation posts for alerting the observers to things happening on their front which can then be examined more closely by optical or other means.

One last ancillary used in observation posts must be mentioned, and that is the image-intensifying surveillance instrument, telescope or binocular. The ability to see at night has transformed the artillery's night-time ability from that of a security fence to that of a precision sniper. At one time, darkness meant the end of accurate observation, and artillery would simply be laid on pre-determined defensive fire zones in front of the infantry; should an attack develop, these zones were engaged in order to form some sort of barrier. But the availability of night vision equipment, whether it be the image-intensifier or the thermal-imager which relies upon infra-red technology, now permits the observer actually to see what is happening on the front and direct accurate fire against it. This, combined with the laser rangefinder which allows fast and accurate determination of range to the target, has removed much of the uncertainty from night-time firing and has improved the artillery's ability to respond to a developing tactical situation.

◄ Another type of laser designator in use by a forward observer team.

TO THE 21ST CENTURY

In September 1988 the Commandant of the US Army Artillery Centre, Fort Sill, presented a 'Master Plan' for the US Field Artillery which defined material and structure requirements demanding that some $6.4 billion be spent by 1994. The Commandant was doubtless enough of a realist to appreciate that there was little or no chance of getting this sort of money, but at least he was applying some ginger to contemporary artillery thinking.

A percipient point which this Master Plan produced was one that has been sadly neglected in the past. We have, over the years, been accustomed to periodically being given the latest figures on the imbalance of NATO armoured forces *vis-à-vis* those of the Warsaw Pact; the ratio of 3:1 in the Warsaw Pact's favour is generally accepted, and has always been brandished as a valid reason for demanding more money for bigger and better tanks. What has rarely been discussed before is the far more serious imbalance in conventional artillery, currently in the order of 7:1 against NATO. In the past fifteen years the Soviet Army has introduced two new towed artillery pieces, six self-propelled systems, four multiple rocket systems and seven new target-acquisition systems. In the same period the USA has introduced one new towed howitzer, one rocket system and one counter-battery radar; the British one towed howitzer and one radar; the French one towed and one self-propelled howitzer; and the remainder of NATO nothing of significance. The Master Plan estimates that the current Soviet artillery facing the US V Corps in Germany could fire 2,000 tons of shells in a 45-minute preparatory fire, with results that can easily be imagined. It must be remembered that to the Soviets, artillery is the Queen of Battle and has always been employed in as great a quantity as their arsenals could produce it. At the crossing of the Vistula, in January 1945, the First Belorussian and First Ukrainian Fronts between them deployed 32,143 guns and mortars with 6,460 tanks and assault guns; it is doubtful if the entire gun strengths of the combined British and American Armies of that time could have mustered so many guns, and, bear in mind, this was merely one operation on a very large front. One can also be sure that in any arms-reduction discussions, while the Soviets may shuffle missile strengths and bargain over tanks, they will dig their heels in at the first suggestion of reducing artillery strength.

It has been customary in the past to shrug off Soviet numerical superiority by pointing to Western technical superiority; but this appears to be a non-starter in the artillery field. From what we can see of Soviet artillery, it is as technically advanced as that of the West, and besides, it would require some formidable technical innovation to overcome that 7:1 ratio.

Technological innovation, as we have already seen, is what the various programmes – AFAS, ISIS, HEL and so forth – are anxious to uncover and put to use; but this is jam tomorrow, and the Commandant of the Artillery Center wants his jam today. The Master Plan, therefore, concentrates on extracting the utmost from what technology is already available, by putting more of it into the hands of troops and utilizing it in the most effective manner. There are any number of useful ideas and devices floating about in laboratories and experimental establishments; what is needed is the finance and motivation to put them to good and effective use.

Human nature being what it is, every nation must at least make the best preparation it can against being surprised, and develop a credible deterrent to try to keep the surprise at bay for as long as possible. Artillery, with its ability to deliver massive destruction at any time of day or night, in any weather, might be thought to be an excellent deterrent. It is, moreover, an ideal defensive weapon, allowing its owner to sit tight and play havoc with the attacking force. But if we examine the equipment strengths of some representative armies we find a most unbalanced picture; with rare exceptions, armies today have two to three times as many tanks as they have artillery pieces. Britain owns 1,471 tanks, 502 guns (the word gun in this context includes howitzers); Germany 4,887 tanks, 1,227 guns; France 1,540 tanks, 779 guns; the USA 13,300 tanks, 5,470 guns; the USSR 53,300 tanks, 29,000 guns. Armies in which the balance goes the other way include Spain with 843 tanks and 1,078 guns; Denmark 210 tanks, 390 guns; Norway 150 tanks, 405 guns, and Sweden with 985 tanks and 1,020 guns.

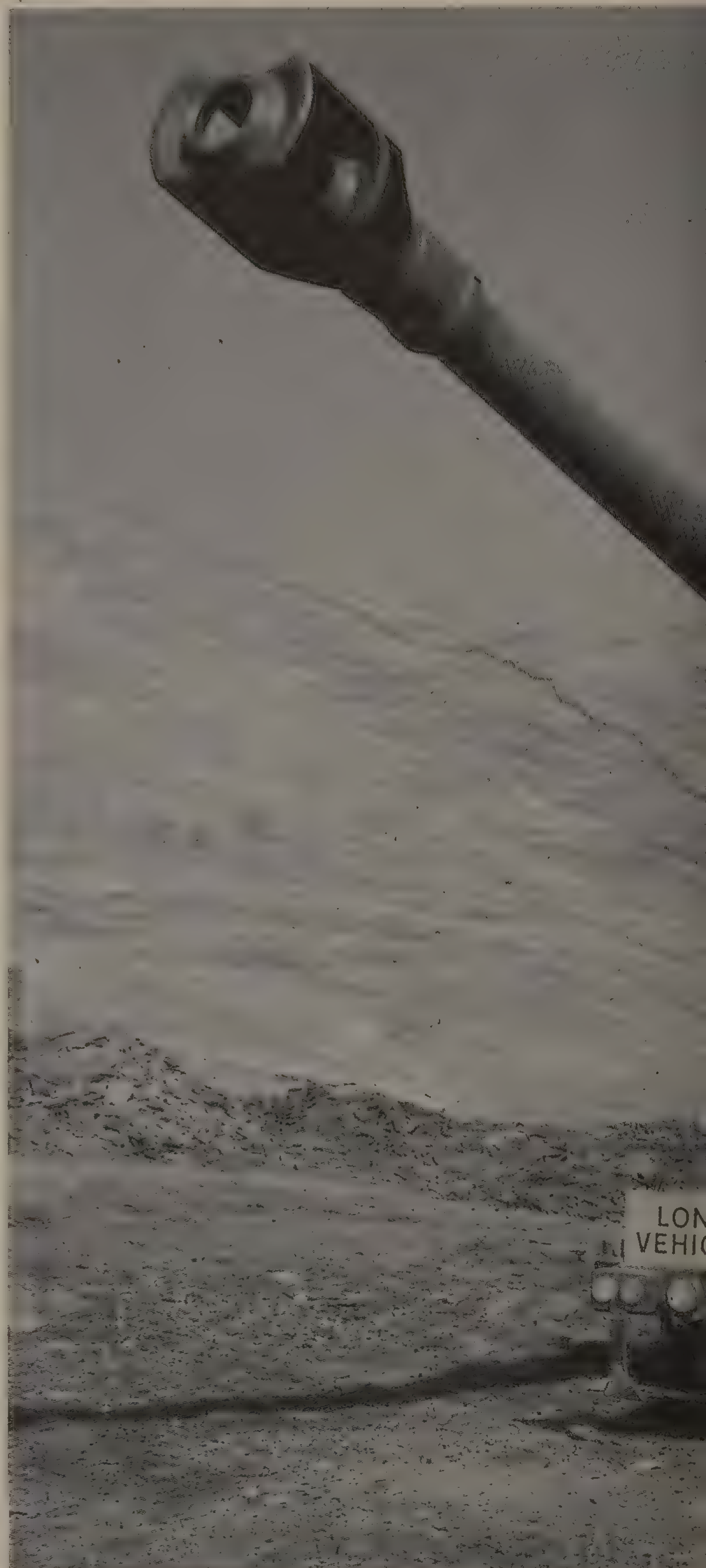
Now the argument runs that in order to counter an opposing army that has a powerful tank force, the defender also needs a powerful tank force, and that is why for the past forty years the tank protagonists have been holding up those 53,300 Soviet tanks with one hand and the begging bowl out with the other. But the theory that the tank's natural enemy is another tank was exploded years ago; the gun is the master of the tank, and this is even more certain with the development of ICM projectiles which allow the gun to reach out and attack armour long before the armour can

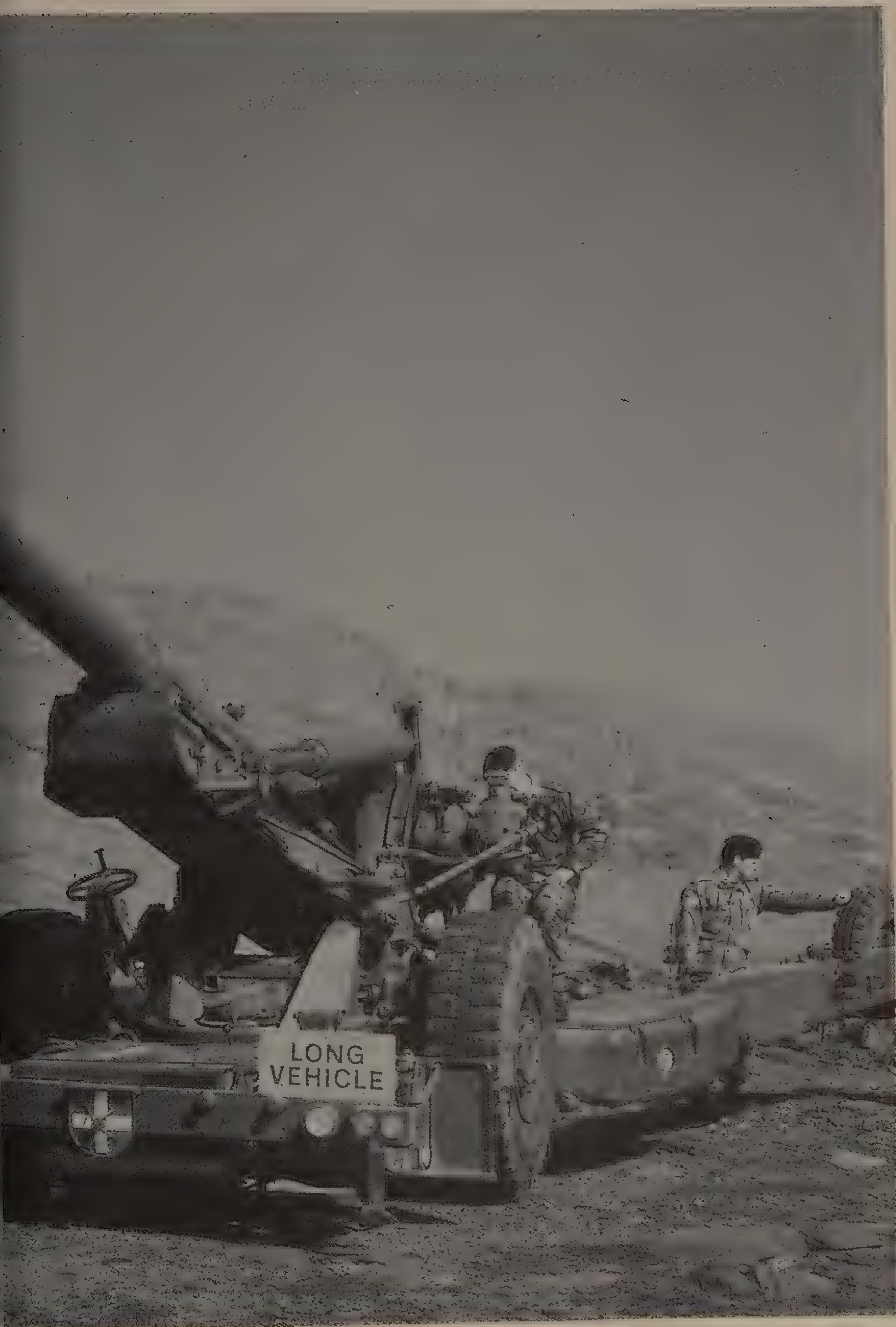
threaten the gun. The tank is an infantry support weapon, just as is the gun; divorce either from the infantry and the infantry becomes vulnerable. Divorce the infantry from the tank and the tank, too, becomes vulnerable. But while the artillery is a support for the infantry, the two are not so closely bound as are the infantry and the tank and attempts to split the two apart are ineffective; the flexibility of artillery command ensures that if a supporting battery is destroyed, another battery five miles away can take over its task without physical movement. If a supporting tank squadron is destroyed, a tank squadron five miles away is entirely useless until it can be brought to the scene.

These and similar considerations begin to suggest that the present balance is entirely wrong. A strong tank force is an admirable thing to have, but it must be covered by a strong and flexible artillery force, otherwise as soon as it begins to manoeuvre it is open to destruction by enemy artillery. If the friendly artillery is only in sufficient strength to deal with the enemy artillery by counter-fire, the armour is starved of support; if the friendly artillery devotes its labour to supporting the armour, it cannot deal effectively with the enemy artillery. And if, as is suggested, the current WP/NATO imbalance is 7:1, the NATO artillery will find itself in just this position, rushing around like a one-armed paper-hanger trying to do everything and achieving nothing.

The adoption of MLRS (the Multiple Launch Rocket System) is one way of attempting to counter the imbalance, by presenting more missiles rather than more barrels. But as we mentioned earlier, there is every indication that MLRS is being seen as a replacement for guns and howitzers rather than as a supplement. This may be due to the pre-ordained establishments which decree that such-and-such a percentage of the army will be artillery; if they wish to increase their firepower they can do so, but without increasing their manpower. But MLRS has application only in certain roles, and replacing conventional artillery with rockets having a minimum range of 6,000 metres is a retrograde step. It is, in fact, weakening the general artillery strength while giving more firepower in a narrowly defined area.

Another argument against increasing artillery strength is that of vulnerability; put more guns on the ground and you provide the enemy with more targets. This argument, though, is based on handling artillery in the manner it has been handled in the past,





The 155mm FH-70 howitzer in firing position. (Vickers Shipbuilding & Engineering)

deploying batteries and battalions in tight little groups. We have seen, by this time, that autonomy – giving the gun the ability to operate independently in space while still operating cohesively as a tactical unit – can provide a solution for this. Several years ago, when the tank imbalance was first being discussed, a gentleman suggested that the easiest solution was to give every able-bodied German male a rocket-launcher to keep under the bed; there would thus be about fifty rocket-launchers arrayed against every invading tank, and by the law of averages one of the fifty should destroy the tank. The figures are not quite the same, but the argument is similar; spread a large number of guns around the countryside and the odds on their surviving improve exponentially, while the chance of their doing damage increases in proportion. So autonomy can reduce the vulnerability threat.

But autonomy brings with it a heavy demand for communications. The air will be thick with channels, all liable to interference by electronic countermeasures. There is a shortage of communications channels; the military forces must be restricted in their use of the ether to leave room for carphones, cab radios, paging devices, CB channels, television and many other vitally important things. I venture to suggest that with an invading army knocking on the door, these will be of zero importance and the military will take what channels it needs without further argument. The threat of ECM still obtains, however, and there is no doubt that artillery held together with radio links is extremely vulnerable. Even the frequency-hopping radio, which flashes from channel to channel many times a second to defeat jamming, has now been threatened by the frequency-hopping jammer. The only hopeful sign is that the electronics industry has shown some remarkable ingenuity over the past thirty years and I am confident that techniques to overcome ECM will arrive during the coming decade. Jamming, moreover, is a two-edged sword; swamping the area with noise jamming will jam everything, not merely the radios of one side.

Autonomous artillery, therefore, is a practical idea even though it has a number of minor problems which will have to be solved before it becomes a commonplace. The next problem is to provide that artillery with targets.

Artillery fire can be divided into three basic types: close support, counter-bombardment, and 'deep fire'. Close support is concerned with the minute-to-minute response to the developing tactical situation, with the actual physical support of the troops on the immediate front. It is the visible sign of support upon which the infantry and armour rely. Counter-bombardment is the suppression of enemy artillery. Deep fire is the engagement of targets other than artillery that are well inside enemy territory and not of immediately apparent tactical significance. These three groups present very different acquisition problems.

Close support is the daily task of forward observers, and they are dealing with things within their purview. As and when they see a likely target they need to be able to locate it as accurately as possible so that this can be converted to gun data. Forty years ago this required a map, a compass and an 'eye for country'; today it requires a laser rangefinder, a compass, night-vision capability – and an eye for country. (Any man can be trained to become a competent observer, but the really outstanding ones are born, not made, and it is this near-indefinable 'eye for country' which distinguishes them, which enables them to co-relate map and terrain so that they instinctively know precisely where anything on the front is in terms of map coordinates.) In addition, the observer needs a communications link so that his observations and fire orders can be sent to the appropriate place without delay or corruption. Finally, bearing in mind the conditions in which the observer works, his equipment needs to be portable and inconspicuous, reliable and simple to operate.

All this is currently available, and can continue to be the standard equipment well into the 21st century; the requirements are well defined and are met in a satisfactory manner, and there is no sense in change for change's sake. The only thing that will need watching in the coming decade is the tendency for well-meaning technicians to add to the observer's load by giving him things which might be useful in certain rare circumstances but which for most of the time are dead weight. A laser designator is useful to bring in a certain class of projectile, but when that projectile is not being used the designator is several pounds of useless machinery.

One of the most insidious arguments for the replacement of equipment with something bigger, heavier and more expensive is that it will improve accuracy. Thus, instead of a magnetic compass weighing a few ounces, the observer will be given an electronic gyro-compass weighing several pounds, on the grounds that it will determine an azimuth to an accuracy of five minutes

of arc instead of thirty. Assuming the target to be 3,000 metres from the observer, this means the displacement of the target's apparent position by 22 metres. Considering the accuracy of the grid reference that will be sent to the guns to start the whole system operating, the inherent accuracy of the gun and the effective area of the bursting shell, this seems to be an unnecessary refinement and one which merely adds to the observer's load.

The inherent accuracy (or lack of it) of the gun is something which those who are not directly associated with artillery fail to understand, and it is the root cause of this false hunt for the ultimate accuracy. Guns are subject to the same laws as anything else, one of which is the law of chance. Sink a gun tube in ten thousand tons of concrete so as to be absolutely immovable and fire 100 shells from it, and the chance of two of those shells falling into the same hole is extremely slight. The 100 shots will be distributed in a rectangle, the length of which will be parallel with the line of fire. The centre of the rectangle will be the 'mean point of impact', the mathematical mean of all the shots. If we divide this length into eight equal portions, 50 per cent of the shots will lie inside the two sectors adjoining the mean point of impact. The remaining 50 per cent will be spread through the other sectors, the incidence of shots reducing as the extremes are approached. A similar division could be done laterally, though the rectangle is usually so narrow that nobody ever bothers to assess its zones. This is entirely in accordance with the normal laws of distribution and should surprise nobody; but it still continues to surprise people who, in all good faith, will propose devices of extreme accuracy for fire control without realizing that no gun will ever be able to take advantage of them. The point is that, for our assumed target, the 50 per cent zone of the gun (which depends upon shell type, charge and range) could be 150 metres long and 15 metres wide, which rather makes argument over 22 metres' accuracy of location a dead letter. There is no benefit to be gained by insisting upon accuracies which the gun cannot meet; it is rather like working out the distance of the moon to three places of decimals – an interesting intellectual exercise of no practical value.

Counter-bombardment demands an entirely different technique for target location; the enemy is not likely to put his guns within view of the forward observer, and discovering their location has to be done by a mixture of old and new technology. The old technology is primitive to modern minds, but still effective; it relies upon examining the craters left by bursting shells to discover the direction of fire and the nature of the weapon. The former can be determined with surprising accuracy by careful analysis of the crater, while the latter relies upon careful study of the fragments. Modern projectiles, with improved fragmentation, no longer leave large chunks of metal from which markings can be read or major dimensions assessed, but even so there will still be pieces capable of expert analysis.

Crater examination is good enough to allow a deduction – that in this area there is probably a battery of heavy guns. Confirmation, and a more precise location, had to be reached by other methods. The conventional method is aerial surveillance, either by manned aircraft or by RPVs, and there seems to be little possibility of any major advance in this area, except perhaps in the improvement of the sensors used. At present there has to be a compromise between the speed of the response and the degree of detail obtained. If the delays inherent in conventional photography are acceptable, the ultimate in fine resolution of detail can be achieved, but if speed is of the essence, digital transmission of information obtained from television or thermal-imaging must be resorted to, and the resolution of fine detail suffers accordingly. If high-speed sensors with high resolution can be achieved within the small space available in RPVs, target acquisition will be considerably improved.

The other option is the use of radar to detect the enemy projectiles in flight and, by extrapolation of the trajectory, determine the location of the gun. Enough has been said about this elsewhere to indicate that it is a formidable problem and one that demands very expensive and complicated equipment. It does, though, have the advantage of being instantly and constantly available; RPVs and aircraft, on the other hand, have to be prepared, briefed or programmed, and sent off to look at some specific area, after which the results have to be analysed. In short, aerial observation is reactive, a response to bombardment. Radar search is interactive, in that it detects the bombardment when it begins and is capable of coming up with an answer within seconds, before the bombardment is completed and before the bombarding weapon has time to displace. On balance, therefore, one is inclined to the belief that aerial observation for counter-bombardment purposes is less cost-effective than radar observation, and that the latter should take over this task.

◀ Gunners of the Swedish Army with the 155mm Bofors FH-77A howitzer. (Bofors AB)

Deep fire involves attacking targets a long way beyond the immediate front, places where concentrations of troops or equipment may be expected, headquarters, communications centres and similar 'nerve centres' of the opposing force. These are not going to be discovered by forward observers or by radar, so that it is this area in which the aerial reconnaissance capability must be deployed. It must also be the area into which intelligence gained by other means is inserted; intelligence from agents, long-range penetration groups, stay-behind parties, satellites or whatever – we need not go too deeply into this. Once again the technology is currently available, and merely needs to be deployed in sufficient numbers. This, of course, is an area in which MLRS will have its principal effectiveness and the proposed numbers would appear to be adequate. But there is also a place for conventional artillery and its destructive power against *matériel*, something which the submunition warheads of MLRS do not provide.

The development of artillery, and artillery systems, into the 21st century will, therefore, be evolutionary rather than revolutionary. Given what we know to be the average time of gestation for complex technical projects, even if the scientists were to demonstrate a workable laboratory model of a liquid-propellant weapon tomorrow, it would be extremely unlikely to appear in service form before the year 2000. As for directed-energy weapons, laser beams and similar devices, I think we can confidently forget them so far as ground artillery is concerned. The artillery weapon of the year 2000 will be what it is in 1989, a tube firing chemical propellant to eject a projectile. It seems probable that the tube will be long, to extract the most benefit from the propellant; progressively rifled so as to throw less strain on the projectile at shot start; and with a chamber contour designed to deliver the highest velocity commensurate with a safe chamber pressure. The mounting will, in the majority of cases, be self-propelled with the capability of autonomous operation. There is still a place for the towed gun, of course, and these will usually be provided with auxiliary propulsion. Whatever the mounting, it will be provided with labour-saving devices for loading, emplacing and displacing, such devices being intended to lessen the load on the operators and, at the same time, reduce the number of operators necessary for the efficient operation of the weapon.

Ammunition is likely to be a mixture of conventional projectiles – in which I include base-bleed and ERFB designs; carrier ICMs loaded with anti-personnel and anti-armour submunitions; and 'smart' ammunition with terminal guidance either of the projectile itself or of submunitions carried within it. These three groups of projectiles tend to divide along the same lines as the targets; conventional shells for close support, ICMs for

counter-bombardment and 'smart' projectiles for deep fire. This is not an immutable division, but one which falls into place quite naturally when one considers the characteristics of the ammunition and the targets.

Target acquisition will continue to use the same sort of equipment as is currently either in use or being discussed, though there will undoubtedly be detail improvements in such things as sensor resolution, gun-detecting radars and observing instruments.

What is going to tie all this together and turn a collection of equipment into a system is the overlying data transmission system. These systems, currently in their early stages, have the potential to harness every aspect of the target acquisition, intelligence and firing elements and provide them with a cohesion, flexibility and response which will increase artillery effectiveness by a very considerable factor. The danger here is that the system could be overloaded with information; not overloaded in the sense that it could contain no more, but overloaded in the sense that when the commander asks for data he could be overwhelmed with what the computer has to tell him. This, it seems, is more probably a question of training the people responsible for putting the information into the system, establishing some sort of filter, and refining the output to essentials. There is a well-known maxim in the computer world, namely 'Garbage In = Garbage Out'; if you load the system with rubbish, it will output rubbish, and firm discipline is needed to avoid this. I do not think that 'artificial intelligence' or 'expert systems' are likely to be of much use here, except perhaps to form an initial filter; it would take something fairly considerable in the computing line to emulate the intelligence, instincts and logic of a trained artillery staff officer with twenty years of experience to draw upon.

Above all else, though, the one vital point about artillery in the year 2000 is that so far as the West is concerned there should be a great deal more of it. The present artillery strength of Western armies appears to be based upon some notional proportionate establishment which bears very little relationship to the responsibilities that will fall upon the artillery arm if war ever breaks out. The potential and capabilities of artillery are ignored largely, I suspect, because to the layman's eye the gun of today seems very little changed from the gun of yesterday or even the day before; and if the gun hasn't changed, how can it keep its place in the modern technological battlefield? I hope that, by now, the answer to this has been made clear. But even if it has not, be assured that even if we only had the guns of yesterday, they could still make their presence felt on tomorrow's battlefield – if we had enough of them. No present-day tank would last long faced with the German 128mm PaK 44 or the British 32pdr, both developed in 1944-5; the German 17cm K18 fired a 63kg shell to 29,600 metres and the 24cm K3 fired a 151kg shell to 37,500 metres; and although air defence artillery has been excluded from our review, the most modern bomber would feel upset if confronted, at 50,000 feet, with the 80lb shell of the British 5.25in AA gun. This is not an argument to revert to obsolete designs, merely figures selected at random to show that the performance we strive for today is not unique; our contribution has been to improve the mechanical features. And since some of these improvements are not readily visible, there is this belief that artillery is some sort of archaic arm which is no longer really significant. On the contrary, artillery is the decisive arm of tomorrow's battlefield just as it was of yesterday's.

However, having said what we consider likely, and what we consider desirable, it is necessary to think of the economics and infrastructure. When theorists are projecting what the shape of military forces may be at some future date, they generally concentrate upon the technology and tell us what ought to be possible, and from that draw up orders of battle and strategic plans. What they rarely take into account is how much money these plans will cost, where the money is to come from, and where the men to man the technology are to be found. And with every day that goes by, these three factors take on greater and greater importance.

To take the last first; manpower. One of the complaints about current artillery is that it is manpower-intensive; a 203mm gun battery fields 28 men to each gun. Not all these men are employed on the weapon; this is the number of men in the battery divided by the number of gun barrels. It might be said, in mitigation, that missiles are far worse, running to perhaps 70–75 men per launcher. At the same time, there is growing resistance to conscription in free countries, and more and more Western armies are volunteer forces. And, parallel with this, there is the undisputed fact that the manpower pool is declining. The birthrate is dropping, a smaller number of young men is available each year as the reservoir from which volunteers come shrinks, and it is probable that the volunteers will be of a lower standard. When the manpower pool shrinks, the

smarter and better-educated young men have a better chance to get ahead, and they are unlikely to volunteer for military service, leaving the services the less clever element. None of this is much consolation for armies keen to equip themselves with high technology. Either the number of men is kept up, in which case standards must decline since lower-grade men must be used; or fewer men must be used, in which case there is the chance that sufficient better-grade men will be available to fill the slots.

Although I have never seen this idea put forward officially, it is probably fair to say that if artillery (or any other military activity for that matter) is automated, mechanized, and endowed with every artifice that technology can provide, there is probably no physical reason why women could not be employed. There are undoubted psychological, sentimental and political reasons against their employment, but if we just leave those aside for a moment and consider the physical aspect, it will be apparent that there is very little barrier. We are promised howitzers with automated ammunition handling and loading, automated gun-laying, and power-actuated spades, trails, wheels, and other apparatus, which means that all the major physical effort has been removed. That this has been done is simply in order to reduce the load and operate the weapon with fewer men, but these same mechanical advantages argue that women could do the job equally well. Bear in mind that during the Second World War women operated searchlight batteries in several armies, and, in the British Army, formed a high proportion of the staff of 'Mixed AA batteries' of 3.7in guns. Officially they operated the fire-control instruments; unofficially, as many elderly ladies will confide, some of them managed to get their hands on to the guns from time to time, largely to prove to themselves that they could do it. So far as I know, none ever served the guns in serious action, nor ever fired a gun at an enemy, but there is no doubt that many girls satisfied themselves that they could, if pushed, have operated a 3.7in AA gun in a satisfactory manner. And if they could manage manually operated guns firing 50lb rounds of ammunition, I should think their modern equivalent could manage an automated 155mm self-propelled howitzer.

But then we come back to the psychological, political and sentimental objections and we have to admit that the idea is pure pie in the sky. Nevertheless, I think that by the year 2000 the employment of women in fire control and the less violently active parts of artillery will have to be given serious consideration if the manpower trap is to be avoided.

Now to consider costs. As we saw above, the US Master Plan will require $6.4 billion for its implementation, and it is not asking for anything that is not currently in existence as a proven device; all it is asking for is a proper scale of issue for all the new ammunition and fire-control equipment currently under consideration. If we now go forward from this and start thinking about provision of totally new equipment – liquid-propellant guns, guided projectiles, automated howitzers and so forth – to a scale that will perhaps halve the current Warsaw Pact/NATO imbalance, the cost will spiral out of sight. It is not unreasonable to assume a cost of $1.5 million for a new-technology howitzer; indeed, on closer examination it seems cheap. But even allowing for that, suppose that NATO decided to replace all its existing self-propelled 155mm howitzers with this new equipment. Based upon the most recent figures in 'The Military Balance', generally accepted as a reliable guide to military strength, this would entail replacing 4,828 pieces of equipment at a cost of $7.24 billion. This does not take any account of what would be necessary in fire-control and target acquisition equipment in order to make these new weapons effective. Nor does it even begin to think about the cost of keeping this force supplied with ammunition, even in peacetime. And as to the cost of keeping it stocked with ammunition in a major war . . . we are no longer talking about iron shells filled with amatol and costing small change, we are talking about 'smart' ammunition in which the price of a rather good car is vaporized at every shot. There is reason to think that future wars will not be won by big battalions but by deep pockets. And please remember we are only discussing artillery; do similar arithmetic for the tanks, missiles, infantry weapons, communications equipment and every other military requirement of the future and the figures beggar the imagination. Can any nation really afford modern war? As with so many things, the Duke of Wellington summed it all up many years ago:

> 'Admitting the truth of the expense, I say that the country has not a choice between Army and no Army, between peace and war. They must have a large and efficient army, one capable of meeting the enemy abroad, or they must expect to meet him at home: and then farewell to all considerations of measures of greater or lesser expense, and to the ease, the luxury and happiness of England.'

ARTILLERY EMPLOYMENT

The following table lists the field artillery and multiple rocket-launchers known to be employed by various armies. The nomenclature is that of the originating country and matches that given in the Data Tables. It must be appreciated that armaments pass through several hands during their lifetime, and that the employment of, say, an American gun does not necessarily imply that it was obtained directly from the USA; it could have had three or four previous owners. The numbers given after the title of the country are the total estimated holdings of guns (and howitzers) and rocket-launchers.

Afghanistan (Guns 800; MLRS 50)
76mm M1938 Mtn (USSR)
76mm M1966 Mtn (USSR)
76mm M1942 (USSR)
85mm D48 (USSR)
100mm M1944 (USSR)
122mm D30 (USSR)
122mm M1938 (USSR)
152mm M1943 (USSR)
152mm D20 (USSR)
132mm BM-13-16 (USSR)

Albania (Guns 1,200; MLRS 100)
57mm M1943 (USSR)
76mm M1942 (USSR)
85mm D44 (USSR)
85mm Type 56 (China)
122mm M1931/37 (USSR)
122mm M1938 (USSR)
122mm Type 60 (China)
130mm Type 59-1 (China)
152mm Type 66 (China)
152mm M1937 (USSR)
152mm M1943 (USSR)
107mm Type 63 RL (China)

Algeria (Guns 800; MLRS 100)
76mm M1942 (USSR)
85mm D44 (USSR)
12mm M1931/37 (USSR)
122mm M1938 (USSR)
122mm D30 (USSR)
122mm D74 (USSR)
122mm SP SO-122 (USSR)
130mm M46 (USSR)
152mm M1937 (USSR)
152mm D20 (USSR)
152mm SP SP-152 (USSR)
122mm BM-21 RL (USSR)
240mm BM-24 RL (USSR)

Angola (Guns 550; MLRS 75)
76mm M1942 (USSR)
85mm D44 (USSR)
122mm D30 (USSR)
122mm SP SO-122 (USSR)
130mm M46 (USSR)
122mm BM-21 RL (USSR)

Argentina (Guns 350; MLRS 50)
105mm M56 (Italy)
105mm M101 (USA)
105mm SP M7 (USA)
155mm M59 (USA)
155mm M114 (USA)
155mm Mod 77
155mm Mod 81
155mm SP Mle F3 (France)
105mm SALM RL
127mm SAPBA RL

Australia (294
105mm M56 (Italy)
105mm Light (UK)
105mm M101 (USA)
140mm 5.5in (UK)
155mm M198 (USA)

Austria (Guns 250; MLRS 20)
85mm M52 (Czech)
105mm M101 (USA)
155mm M59 (USA)
155mm M114 (USA)
155mm GH-N-45
155mm SP M109/109A2 (USA)
130mm Type 51 RL

Bahrain (20)
105mm Light (UK)
155mm M198 (USA)

Bangladesh (100)
76mm Type 54 (China)
87mm 25pdr (UK)
105mm M56 (Italy)
105mm M101 (USA)
122mm Type 54 (China)

Belgium (Guns 175)
105mm M101 (USA)
105mm M56 (Italy)
155mm M59 (USA)
155mm M114 (USA)
155mm SP M109/109A2 (USA)
203mm M115 (USA)
203mm SP M110A2 (USA)

Benin (25)
105mm M101 (USA)
122mm D30 (USSR)
130mm M46 (USSR)

Bolivia (50)
75mm M1935 (Sweden)
75mm M116 (USA)
105mm M101 (USA)

Botswana (10)
105mm Light (UK)
105mm M56 (Italy)

Brazil (Guns 750; MLRS 80)
105mm M101 (USA)
105mm M102 (USA)
105mm M56 (Italy)
105mm SP M108 (USA)
155mm M114 (USA)
108mm 108-R RL
180mm SS-40 RL
300mm SS-60 RL

Brunei (24)
105mm Light (UK)

Burkina Faso (Guns 20; MLRS 10)
105mm M101 (USA)
105mm M56 (Italy)
107mm Type 63 RL (China)

Burma (300)
76mm M48 Mtn
87mm 25pdr (UK)
140mm 5.5in (UK)

Burundi (20)
76mm M116 (USA)
76mm Type 54 (China)

Cameroun (22)
75mm M116 (USA)
85mm Type 56 (China)
105mm M101 (USA)

Canada (275)
105mm M101 (USA)
105mm M56 (Italy)
155mm M114 (USA)
155mm M109A1 (USA)

Chad (15)
76mm M1942 (USSR)
105mm M101 (USA)
122mm D30 (USSR)

Chile (150)
105mm M56 (USA)
105mm M101 (USA)
155mm M114 (USA)
155mm SP Mle F3 (France)

China (Guns 13,000; MLRS 4,500)
76mm Type 54
85mm Type 56
100mm Type 59
122mm Type 54
122mm Type 60
122mm SP Type 54-1
130mm Type 59-1
152mm Type 54
152mm Type 66
152mm SP Type 83
107mm Type 81 RL
122mm Type 83 RL
122mm Type 81 RL
130mm Types 63 & 70 RL
132mm BM-13-16 RL (USSR)
140mm BM-14-16 RL (USSR)
273mm Type 83 RL
284mm Type 74 RL

Colombia (50)
105mm M101 (USA)

Congo (Guns 50; MLRS 8)
57mm M1943 (USSR)
75mm M116 (USA)
76mm M1942 (USSR)
85mm Type 56 (China)
85mm D48 (USSR)
100mm M1944 (USSR)
12mm M1938 (USSR)
122mm Type 54 (China)
122mm D30 (USSR)
130mm M46 (USSR)
122mm BM-21 RL (USSR)

Cuba (Guns 1,500; MLRS 200)
76mm M1942 (USSR)
85mm D44 (USSR)
85mm SD44 (USSR)
85mm D48 (USSR)
122mm D75 (USSR)
122mm M1931/37 (USSR)
122mm D30 (USSR)
122mm M1938 (USSR)
130mm M46 (USSR)
152mm M1937 (USSR)
152mm M1943 (USSR)
152mm D20 (USSR)
122mm BM-21 RL (USSR)
140mm BM-14 RL (USSR)
240mm BM-24 RL (USSR)

Cyprus (Guns 160; MLRS 8)
75mm M116 (USA)
76mm M1942 (USSR)
87mm 25pdr (UK)
100mm M1944 (USSR)
105mm M56 (Italy)
105mm M101 (USA)
128mm M77 (Yugoslavia)

Denmark (400)
105mm M101 (USA)
155mm M59 (USA)
155mm M114 (USA)
155mm SP M109A2 (USA)
203mm M115 (USA)

Djibouti (20)
105mm M56 (Italy)

Dominican Republic (25)
105mm M101 (USA)
105mm L/22 (Sweden)

Ecuador (85)
105mm M101 (USA)
105mm M56 (Italy)
155mm M198 (USA)
155mm SP Mle F3 (France)

Egypt (Guns 800; MLRS 300)
76mm M1942 (USSR)
85mm D44 (USSR)
100mm M1944 (USSR)
122mm M1931/37 (USSR)
122mm D30 (USSR)
122mm M1938 (USSR)
122mm Type 60 (China)
130mm M46 (USSR)
130mm Type 59-1 (China)
152mm M1943 (USSR)
152mm D20 (USSR)
155mm M109A2 (USA)
180mm S23 (USSR)
80mm VAP RL
122mm BM-21 (USSR)
130mm M-51 (Czech)
132mm BM-13-16 (USSR)
140mm BM-14-16 (USSR)

El Salvador (50)
105mm M56 (Italy)
105mm M101 (USA)
105mm M102 (USA)
155mm M114 (USA)

Ethiopia (Guns 750; MLRS 30)
75mm M116 (USA)
85mm D48 (USSR)
105mm M101 (USA)
122mm D30 (USSR)
122mm M1938 (USSR)
122mm SP SO-122 (USSR)
130mm M46 (USSR)
152mm M1943 (USSR)
155mm M114 (USA)
155mm SP M109 (USA)
122mm BM-21 RL (USSR)

Finland (800)
105mm M61/37
105mm M31 How
122mm D30 (USSR)
122mm M1938 (USSR)
122mm M60
130mm M1954 (USSR)
150mm M40
152mm M1938 (USSR)
155mm K83

France (800)
105mm M101 (USA)
105mm M56 (Italy)
105mm SP Mk 61
155mm M50
155mm TR
155mm SP F3
155mm SP GCT

Gabon (Guns 15; MLRS 8
76mm Type 54 (China)
105mm M101 (USA)
140mm RPU-14 RL (USSR)

Germany, West (Guns 1,300; MLRS 211)
105mm M56 (Italy) (Modified)
105mm M101 (USA)
155mm M114 (USA)
155mm FH-70
155mm SP M109G (USA) (Modified)
155mm SP M109A2 (USA)
110mm LARS RL
227mm MLRS (USA)

Ghana (25)
76mm M1942 (USSR)
87mm 25pdr (UK)
105mm Light (UK)

Greece (1,400)
75mm M116 (USA)
87mm 25pdr (UK)
105mm M101 (USA)
105mm M56 (Italy)
105mm SP M52 (USA)
105mm SP M108 (USA)
155mm M59 (USA)

155mm M114 (USA)
155mm M198 (USA)
155mm SP M44 (USA)
155mm SP M109/A1/A2 (USA)
175mm SP M107 (USA)
203mm M115 (USA)
203mm SP M110 (USA)

Guatemala (125)
75mm M116 (USA)
105mm M101 (USA)

Guinea (28)
76mm M1942 (USSR)
85mm D44 (USSR)
122mm M1931/37 (USSR)
130mm M46 (USSR)

Guinea-Bissau (27)
85mm D44 (USSR)
122mm M1938 (USSR)
122mm D30 (USSR)
130mm M46 (USSR)

Guyana (6)
130mm M46 (USSR)

Haiti (10)
75mm M116 (USA)
105mm M101 (USA)

Honduras (40)
75mm M116 (USA)
105mm M101 (USA)
105mm M102 (USA)
155mm M198 (USA)

India (Guns 2,200; MLRS 120)
75mm Mtn How
76mm M48 (USSR)
85mm D48 (USSR)
100mm M1944 (USSR)
105mm Field Gun
105mm M56 (Italy)
105mm Abbot (UK)
130mm M46 (USSR)
130mm SP M46 Vijayanta
140mm 5.5in (UK)
152mm D20 (USSR)
180mm S23 (USSR)
203mm M115 (USA)
122mm BM-21 RL (USSR)

Indonesia (350)
76mm M48 (USSR)
76mm M1942 (USSR)
105mm Light (UK)
105mm M56 (Italy)
105mm M101 (USA)
122mm M1938 (USSR)

Ireland (60)
87mm 25pdr (UK)
105mm Light (UK)
105mm M56 (Italy)

Iran/Iraq
In the wake of the recent war, the current holdings of Iran or Iraq are almost impossible to categorize due to clandestine purchases, loss, capture and other factors. It would be fair to say that anything obtainable and capable of shooting has been used by one or both of the countries in the past nine years.

Israel (Guns 850; MLRS 200)
105mm M101 (USA)
122mm D30 (USSR)
130mm M46 (USSR)
155mm M114 (USA)
155mm M71
155mm SP M109/A1
155mm SP L/33
175mm SP M107 (USA)
203mm SP M110 (USA)
122mm BM-21 RL (USSR)
160mm LAR RL
240mm BM-24 (USSR)
290mm MAR-290

Italy (1,200)
105mm M56
105mm M101 (USA)
155mm FH-70
155mm M59 (USA)
155mm M114 (USA)
155mm SP M109 (USA)
175mm SP M107 (USA)
203mm M115 (USA)
203mm SP M110 (USA)

Ivory Coast (8)
105mm M101 (USA)

Japan (Guns 785; MLRS 120)
75mm M116 (USA)
105mm M101 (USA)
105mm SP M52 (USA)
105mm SP Type 74
155mm M114 (USA)
155mm FH-70
155mm M59 (USA)
155mm SP M44 (USA)
155mm SP Type 75
203mm M115 (USA)
203mm SP M110A2 (USA)
130mm Type 67 RL
130mm Type 75 RL

Jordan (250)
105mm M101 (USA)
105mm M102 (USA)
155mm M59 (USA)
155mm M114 (USA)
155mm GH-N-45 (Austria)
155mm SP M44 (USA)
155mm SP M109/A1/A2 (USA)
203mm M115 (USA)
203mm M110A1/A2 (USA)

Kampuchea (Guns 350; MLRS 100)
76mm M1942 (USSR)
122mm D30 (USSR)
122mm Type 54 (China)
122mm Type 60 (China)
122mm M1931/37 (USSR)
130mm Type 59-1 (China)
107mm Type 63 RL (China)
132mm BM-13-16 RL (USSR)
140mm BM-14-16 RL (USSR)

Kenya
105mm M56 (Italy)
105mm Light (UK)

Korea, North (Guns 6,000; MLRS 1,800)
76mm M1942 (USSR)
85mm D44 (USSR)
85mm Type 56 (China)
85mm D48 (USSR)
100mm M1944 (USSR)
122mm M1931/37 (USSR)
122mm M1938 (USSR)
122mm D74 (USSR)
122m Type 54 (China)
122mm Type 60 (China)
122mm D30 (USSR)
122mm SP Howitzer
130mm M46 (USSR)
130mm Type 59-1 (China)
130mm SP M1975
152mm M1937 (USSR)
152mm M1938 (USSR)
152mm Type 66 (China)
152mm SP M1974
152mm SP M1977
170mm SP M1985
180mm SP M1978
107mm Type 63 RL (China)
122mm BM-21 RL (USSR)
130mm Type 63 RL (China)
140mm RPU-14 RL (USSR)
140mm BM-14-16 RL (USSR)
200mm BMD-20 RL (USSR)
240mm BM-24 RL (USSR)

Korea, South (Guns 3,500; MLRS 140)
105mm M101 (USA)
105mm M102 (USA)
105mm KH-178
105mm SP M52 (USA)
155mm KH-179
155m M59 (USA)
155mm M114 (USA)
155mm SP M109A2 (USA)
175mm SP M107 (USA)
203mm M115 (USA)
203mm SP M110 (USA)
130mm Kooryong RL

Kuwait (60)
87mm 25pdr (UK)
155mm M114 (USA)
155mm SP Mle F3 (France)

Laos (140)
75mm M116 (USA)
105mm M101 (USA)
122mm D30 (USSR)
155mm M114 (USA)

Lebanon (500)
105mm M102 (USA)
122mm M1938 (USSR)
130mm M46 (USSR)
155mm Mle 50 (France)
155mm M114 (USA)
155mm M198 (USA)

Liberia (Guns 11; MLRS 4)
105mm M56 (Italy)
105mm M101 (USA)
122mm BM-21 RL (USSR)

Libya (Guns 1,700; MLRS 600)
105mm M101 (USA)
122mm D30 (USSR)
122mm D74 (USSR)
122mm SP SO-122 (USSR)
130mm M46 (USSR)
152mm D20 (USSR)
152mm SP SP-152 (USSR)
152mm SP Dana (Czech)
155mm M114 (USA)
155mm SP Palmaria (Italy)
155mm M109 (USA)
107mm Type 63 RL (China)
122mm BM-21 RL (USSR)
130mm M51 RL (Czech)

Madagascar (50)
76mm M1942 (USSR)
105mm M101 (USA)
122mm Type 60 (China)
122mm D30 (USSR)
130mm Type 59-1 (China)

Malawi (12)
105mm Light (UK)

Malaysia (210)
105mm M102 (USA)
105mm M56 (Italy)
140mm 5.5in (UK)

Mali (Guns 24; MLRS 2)
85mm D44 (USSR)
100mm M1944 (USSR)
122mm D30 (USSR)
130mm M46 (USSR)
122mm BM-21 RL (USSR)

Mexico (85)
75mm M116 (USA)
105mm M101 (USA)
105mm SP M7 (USA)

Morocco (Guns 500; MLRS 25)
76mm M1942 (USSR)
85mm D44 (USSR)
105mm M56 (Italy)
105mm M101 (USA)
105mm Light (UK)
105mm SP Mk 61 (France)
122mm D30 (USSR)
130mm M46 (USSR)
152mm M1937 (USSR)
155mm M114 (USA)
155mm SP M109A1 (USA)
155mm SP F3 (France)
122m BM-21 RL (USSR)

Mozambique (Guns 250; MLRS 30)
76mm M1942 (USSR)
85mm D44 (USSR)
100mm M1944 (USSR)
122mm M1938 (USSR)
130mm M46 (USSR)
152mm M1943 (USSR)
122mm BM-21 RL (USSR)

Netherlands (500)
105mm M101 (USA)
155mm M114 (USA)
155mm SP M109/A2 (USA)
203mm M115 (USA)
203mm SP M110A2 (USA)

New Zealand (60)
105mm M56 (Italy)
105mm Light (UK)
140mm 5.5in (UK)

Nicaragua (Guns 150; MLRS 36)
76mm M1942 (USSR)
105mm M101 (USA)
122mm M1938 (USSR)
122mm D30 (USSR)
152mm D20 (USSR)
122mm BM-21 RL (USSR)

Nigeria (500)
76mm M1942 (USSR)
105mm Light (UK)
105mm M56 (Italy)
122mm D74 (USSR)
130mm M46 (USSR)
155mm FH-77B (Sweden)
155mm SP Palmaria (Italy)

Norway (425)
105mm M101 (USA)
155mm M114 (USA)
155mm SP M109 (USA)

Oman (100)
87mm 25pdr (UK)
105mm Light (UK)
130mm M46 (USSR)
130mm Type 59-1 (China)

Pakistan (Guns 1,700; MLRS 150)
75mm M116 (USA)
87mm 25pdr (UK)
85mm Type 56 (China)
100mm Type 59 (China)
105mm M101 (USA)
122mm Type 54 (China)
130mm Type 59-1 (China)
130mm M46 (USSR)
152mm M1937 (USSR)
155mm M59 (USA)
155mm M114 (USA)
155mm M198 (USA)
155mm SP M109 (USA)
203mm SP M110A2 (USA)
122mm BM-21 RL (USSR)

Paraguay (80)
75mm M1927/34 Mtn (France)
105mm M1927 Mtn (France)
105mm M101 (USA)

Peru (Guns 250; MLRS 14)
105mm M101 (USA)
105mm M56 (Italy)
122mm D30 (USSR)
122mm D74 (USSR)
130mm M46 (USSR)
155mm M114 (USA)
122mm BM-21 RL (USSR)

Philippine Republic (275)
105mm M56 (Italy)
105mm M101 (USA)
155mm M114 (USA)
155mm M68 (Israel)

Portugal (150)
105mm M101 (USA)

155mm M114 (USA)
155mm M109A2 (USA)

Qatar (15)
87mm 25pdr (UK)
155mm SP Mle F3 (France)

Rwanda (12)
105mm M101 (USA)

Saudi Arabia (Guns 550; MLRS 25)
105mm M56 (Italy)
105mm M101 (USA)
105mm M102 (USA)
155mm M114 (USA)
155mm FH-70
155mm M198 (USA)
155mm SP M109A1/A2 (USA)
155mm SP GCT (France)
203mm SP M110 (USA)
127mm SS-30 RL (Brazil)

Senegambia (12)
75mm M116 (USA)
105mm M101 (USA)
155mm Mle 50 (France)

Seychelles (Guns 4; MLRS 4)
122mm D30 (USSR)
122mm BM-21 RL (USSR)

Singapore (100)
155mm M71 (Israel)
155mm M114 (USA)
155mm FH-88

Somalia (250)
76mm M1942 (USSR)
85mm D44 (USSR)
85mm D48 (USSR)
100mm M1944 (USSR)
122mm Type 60 (China)
122mm D30 (USSR)
122mm M1931/37 (USSR)
122mm M1938 (USSR)
130mm Type 59-1 (China)
152mm M1931 (USSR)
152mm D20 (USSR)

South Africa (Guns 200; MLRS 20)
140mm 5.5in (UK)
155mm G5
155mm SP G6
127mm Valkiri RL

Spain (Guns 1,300; MLRS 30)
105mm M56 (Italy)
105mm M26
105mm SP M52 (USA)
105mm SP M108 (USA)
155mm SB 139
155mm M114 (USA)
155mm M109 (USA)
155mm M44 (USA)
175mm M107 (USA)
203mm M115 (USA)
203mm SP M110 (USA)
140mm Teruel RL

Sri Lanka (80)
76mm M1948 (Yugoslavia)
85mm Type 56 (China)
87mm 25pdr (UK)

Sudan (300)
85mm D44 (USSR)
85mm D48 (USSR)
100mm M1944 (USSR)
105mm M101 (USA)
122mm M1938 (USSR)
122mm Type 54 (China)
122mm D30 (USSR)
122mm Type 60 (China)
130mm M46 (USSR)
130mm M59-1 (China)
155mm SP F3 (France)

Sweden (1,020)
105mm 4140
150mm M39
155mm FH-77A
155mm M50
155mm SP Bandkanon

Switzerland (Guns 1,350; MLRS 50)
105mm M35
105mm M46
155mm M50
155mm SP M109 (USA)
81mm RWK-014 RL

Syria (Guns 3,000; MLRS 200)
85mm D44 (USSR)
100mm M1944 (USSR)
122mm M1938 (USSR)
122mm D30 (USSR)
122mm SP SO-122 (USSR)
130mm M46 (USSR)
152mm M1943 (USSR)
152mm M1937 (USSR)
152mm M1876 (USSR)
180mm S23 (USSR)
122mm BM-21 RL (USSR)
220mm BM-27 RL (USSR)
240mm BM-24 RL (USSR)

Taiwan (Guns 2,000; MLRS 100)
75mm M116 (USA)
105mm M101 (USA)
105mm SP M108 (USA)
155mm M59 (USA)
155mm M114 (USA)
155mm SP M44 (USA)
155mm SP M109 (USA)
203mm M115 (USA)
203mm M110A2 (USA)
240mm M1 (USA)
117mm Kung Feng VI RL
126mm Kung Feng III/IV RL

Tanzania (Guns 350; MLRS 50)
76mm M1942 (USSR)
76mm Type 54 (China)
85mm Type 56 (China)
122mm M1931/37 (USSR)
122mm D30 (USSR)
122mm Type 54 (China)
122mm Type 60 (China)
130mm Type 59-1 (China)
130mm M46 (USSR)
122mm BM-21 RL (USSR)

Thailand
105mm M56 (Italy)
105mm M101 (USA)
130mm Type 59-1 (China)
155mm M68 (Israel)
155mm M71 (Israel)
155mm M114 (USA)
155mm GC-45 (Austria)
155mm M198 (USA)

Togo (4)
105mm M101 (USA)

Tunisia (100)
105mm M101 (USA)
105mm SP M108 (USA)
155mm M114 (USA)
155mm Mle 50 (France)
155mm SP M109A2 (USA)

Turkey (2,000)
75mm M116 (USA)
105mm M101 (USA)
105mm M102 (USA)
105mm SP M52 (USA)
105mm SP M108 (USA)
155mm M59 (USA)
155mm M114 (USA)
155mm SP M44 (USA)
155mm M109 (USA)
175mm SP M107 (USA)
203mm M115 (USA)

Uganda (85)
76mm M1942 (USSR)
122mm M1938 (USSR)

United Arab Emirates (75)
87mm 25pdr (UK)
105mm Light (UK)
105mm M56 (Italy)
155mm SP Mle F3 (France)

USSR (Guns 29,000; MLRS 7,000)
76mm M1938
76mm M1966
76mm M1942
85mm D44
85mm D48
100mm T12
122mm M1938
122mm D30
130mm M46
152mm D1
152mm D20
152mm M1976
152mm SP SO-152
152mm SP SP-152
180mm S23
203mm SP SO-203
122mm BM-21 RL
122mm RM-70 RL
122mm M1975 RL
122mm M1976 RL
140mm BM-14-16/17 RL
220mm BM-27 RL
240mm BM-24 RL

United Kingdom (Guns 525; MLRS 4)
105mm Light Gun
105mm SP Abbot
155mm FH-70
155mm SP M109A2 (USA)
203mm SP M110 (USA)
227mm MLRS (USA)

USA (Guns 5,750; MLRS 300)
105mm M101
105mm M102
105mm M119 (UK)
155mm M114
155mm M198
155mm SP M109/A1/A2/A3
203mm SP M110A1/A2
227mm MLRS

Uruguay (60)
75mm M1935 (Sweden)
105mm M101 (USA)
105mm M102 (USA)
155mm M114 (USA)

Venezuela (Guns 130; MLRS 25)
105mm M56 (Italy)
105mm M101 (USA)
155mm SP Mle F3 (France)
160mm LAR RL (Israel)

Vietnam (Guns 2,000; MLRS 300)
76mm M1942 (USSR)
85mm D44 (USSR)
85mm D48 (USSR)
100mm M1944 (USSR)
105mm M101 (USA)
105mm M102 (USA)
122mm D30 (USSR)
122mm D74 (USSR)
122mm M1931/37 (USSR)
122mm M1938 (USSR)
122mm Type 60 (China)
130mm M46 (USSR)
130mm Type 59-1 (China)
152mm Type 66 (China)
152mm D20 (USSR)
152mm M1937 (USSR)
152mm M1943 (USSR)
155mm M114 (USA)
155mm SP M109 (USA)
203mm SP M110 (USA)
107mm Type 63 RL (China)
122mm BM-21 RL (USSR)
140mm BM-14-16 RL (USSR)

Warsaw Pact
All Warsaw pact countries deploy Soviet equipment and it would be pointless to reiterate the same list for every country; the only addition to this is Czechoslovakia which has its own 85mm M52 and 152mm SP Dana equipments. The estimated gun and MLRS strengths of the WP armies are:
Bulgaria Guns 1,800; MLRS 100
Czechoslovakia Guns 700; MLRS 325
Germany, East Guns 800; MLRS 200
Hungary Guns 500; MLRS 50
Poland Guns 2,200; MLRS 400
Romania Guns 1,200; MLRS 350

Yemen (North) (Guns 300; MLRS 65)
76mm M1942 (USSR)
105mm M101 (USA)
105mm M102 (USA)
122mm M1931/37 (USSR)
155mm M114 (USA)
122mm BM-21 RL (USSR)

Yemen (South) (Guns 450; MLRS 50)
87mm 25pdr (UK)
76mm M1942 (USSR)
85mm D44 (USSR)
122mm M1938 (USSR)
130mm M46 (USSR)
122mm BM-21 RL (USSR)
140mm BM-14 RL (USSR)

Yugoslavia (Guns 3,000; MLRS 250)
76mm M48
76mm M1942 (USSR)
85mm D44 (USSR)
100mm T12 (USSR)
105mm M56 (Italy)
105mm M101 (USA)
105mm SP M7 (USA)
122mm D30 (USSR)
122mm M1931/37 (USSR)
122mm M1938 (USSR)
122mm SP 2S1 (USSR)
130mm M46 (USSR)
152mm M1937 (USSR)
152mm D20 (USSR)
155mm M65
155mm M59 (USA)
155mm M114 (USA)
128mm M77 RL
128mm M63 RL

Zaire (Guns 135; MLRS 20)
75mm M116 (USA)
85mm Type 56 (China)
122mm M1938 (USSR)
122mm D30 (USSR)
122mm Type 60 (China)
130mm Type 59-1 (China)
152mm Type 66 (China)
107mm Type 63 RL (China)

Zambia (Guns 165; MLRS 50)
105mm M101 (USA)
105mm M56 (Italy)
122mm D30 (USSR)
122mm BM-21 RL (USSR)

Zimbabwe (90)
76mm M1942 (USSR)
87mm 25pdr (UK)
105mm M56 (Italy)
105mm Light (UK)
122mm Type 60 (China)
140mm 5.5in (UK)

Towed Equipments

Abbreviations: APU – Auxiliary Power Unit; G – Gun; H – Howitzer; Mtn – Mountain; ST – Split Trail; 3L – three-legged trail; 4L – four-legged trail

Calibre mm	Model	Type	Country	Carriage	Wt kg	Barrel Cals	Elevation °	Traverse on carriage °	Shell Wt kg	Muzzle Velocity m/sec	Max Range m	Rate of fire rpm	Remarks
57	M1943	G	USSR	ST	1,150	70	−5 +25	56	3.8	700	8,400	15	Primary employment anti-tank
75	M116	MtnH	USA	Box	653	15	−5 +45	6	8.3	381	8,790	6	Pack howitzer
76	M1942	G	USSR	ST	1,116	45	−5 +37	55	6.2	680	13,290	14	
76	M1938	MtnG	USSR	Box	1,450	21	−5 +65	5	6.3	495	10,100	10	Pack howitzer
76	M1966	MtnG	USSR	ST	780	21	−5 +65	50	6.2	550	11,000	10	
76	M48B1	MtnH	Yugoslavia	ST	705	15.5	−15 +45	50	6.2	398	8,600	7	Pack; with shield & muzzle brake
85	Type 56	G	China	ST	1,750	55	−7 +35	54	9.6		15,650	15	Based on Soviet D44
85	M52	G	Czechoslovakia	ST	2,095	56	−6 +38	60	9.5	805	16,150	15	Primary employment anti-tank
85	D44	G	USSR	ST	1,725	55	−7 +35	54	9.5	805	16,150	10	
85	D48	G	USSR	ST	2,350	76	−6 +35	54	9.3	1,000	18,970	10	Primary employment anti-tank
85	SD44	G	USSR	ST/APU	2,250	55	−7 +35	54	9.6	792	15,650	10	
87	25pdr	GH	UK	Box	1,800	27	−5 +40	8	11.3	518	12,250	5	
100	Type 59	G	China	ST	3,450	60	−5 +45	50	15.6	895	20,000	7	Based on Soviet M1944
100	M53	G	Czechoslovakia	ST	4,280	65	−6 +42	60	15.6	900	21,000	10	Primary employment anti-tank
100	M1944 (BS3)	G	USSR	ST	3,650	60	−5 +45	58	15.6	900	21,000		
100	T12	G	USSR	ST	3,000	80	−10 +20	27	5.5	1,500	1,200	10	Smoothbore anti-tank gun
105	M61/37	H	Finland	ST	1,800	30	−6 +45	54	14.9	600	13,400	8	
105	LTR	G	France	ST	1,250	30	−5 +70	45	16.2		15,500	13	Also fires USM1 ammunition
105	L/35	H	West Germany	ST	2,500	35.5	−5 +65	45	15	640	14,500	8	Modified US M101 with longer barrel
105	Light Mk 2	G	India	Box	2,275	37	−5 +73	10	16	700	17,425	4	
105	M56	H	Italy	ST	1,273	14	−7 +65	18-28	15	420	10,575	8	Traverse dependent on elevation
105	KH178	H	S Korea	ST	2,650	34	−5 +65	45	15	662	14,700	8	Modified US M101

Calibre mm	Model	Type	Country	Carriage	Wt kg	Barrel Cals	Elevation °	Traverse on carriage °	Shell Wt kg	Muzzle Velocity m/sec	Max Range m	Rate of fire rpm	Remarks
105	L/26	G	Spain	ST	1,950	26	−5 +45	50	15.3	443	11,450	6	Also fires IS M1 ammunition
105	4140	H	Sweden	4L	2,600	28	−5 +65	360	15.5	610	14,600	8	
105	M35	G	Switzerland	ST	3,840	42	−5 +45	60	15.3	800	21,000	5	Bofors 1935 design, license-built
105	M46	H	Switzerland	ST	1,850	22	0 +65	60	15.2	490	10,000		Bofors, license-built
105	Light	G	UK	Box	1,818	30	−5 +70	10	16	708	17,000	6	Also barrel to fire US M1 ammunition
105	M101A1	H	USA	ST	2,220	22.5	−5 +66	45	15	473	11,160	3	
105	M102	H	USA	Box	1,496	32	−5 +75	0	15	494	11,500	3	Traverse 360° on platform
105	M56	H	Yugoslavia	ST	2,180	28	−12 +68	52	15	570	13,000	7	Modified US M101A1
122	Type 54	H	China	ST	2,500	23	−3 +60.5	50	21.7	515	11,800	6	Based on Soviet M1938
122	M60	G	Finland	ST	9,500	50	−5 +50	90	25	950	25,500		
122	122/46	G	Spain	ST	7,800		−4 +65	57	22	830	20,000		Reserve Army only
122	M1931 /37	G	USSR	ST	8,050	45	−2 +65	58	25	800	20,800	6	
122	M1938 (M30)	H	USSR	ST	2,500	23	−3 +63.5	50	21.8	515	11,800	6	
122	M1955 (D74)	G	USSR	ST	6,000	45	−2 +50	60	25.5	800	21,000	7	
122	D30	H	USSR	3L	5,000	33	−5 +65	360	21.3	690	15,300	8	
122	D74	G	USSR	ST	5,550	52	−5 +45	58	27.3	885	24,000	7	
130	Type 59-1	G	China	ST	6,300	50	−2.5 +45	56	33.4	930	27,500	7	Based on Soviet M1946
130	M1946	G	USSR	ST	8,620	50	−2.5 +46	50	33.4	930	27,000	7	
140	5.5in	G	UK	ST	5,850	35	−5 +45	60	37.2	595	16,450	2	
150	m/39	H	Sweden	ST	5,720	24	−5 +66	45	41.5	580	14,600	4	
152	Type 66	H	China	ST	5,720	34	−5 +45	58	43.5	655	17,230	6	Based on Soviet M1955
152	M1937 (ML20)	GH	USSR	ST	8,073	32	−2 +65	58	43.5	655	17,265	4	
152	M1943 (D1)	H	USSR	ST	3,600	25	−3 +63.5	35	39.9	508	12,400	4	
152	M1955 (D20)	H	USSR	ST	5,900	37	−2 +63	60	48	655	18,000	4	
152	M1976	G	USSR	ST	9,800	50	−2 +57	50			27,000		No further information available
155	Model 81	H	Argentina	ST	8,000	33	0 +67	70	43	765	22,000	4	
155	GH-N-45	H	Austria	ST/APU	12,382	45	−4 +72	70	45.4		30,300	2	

Calibre mm	Model	Type	Country	Carriage	Wt kg	Barrel Cals	Eleva-tion °	Traverse on carriage °	Shell Wt kg	Muzzle Velocity m/sec	Max Range m	Rate of fire rpm	Remarks
155	M114 /39	H	Austria	ST	6,500	39			45.4		24,400	2	Improved US M114 with new barrel
155	GC45	H	Belgium	ST	8,222	45	−5 +69	80	45.4	897	30,000	4	
155	WA021	GH	China	ST	9,500	45	−5 +72	70	45.5	897	30,000	2	
155	M75	H	Finland	ST	9,500	39	−5 +52	90	43.6	850	24,000	4	
155	M50	H	France	ST	8,200	23	−4 +69	80	43.8	647	17,750	4	
155	M68	H	Israel	ST	9,500	33	−5 +52	90	43.7	725	21,000	4	
155	M71	H	Israel	ST	9,200	39	−3 +52	84	43.7		23,500	4	
155	839P	H	Israel	ST/APU	10,850	39	−3 +70	78	43.5		23,500	4	
155	845P	H	Israel	ST/APU	11,700	45	−3 +70	78	43.5		25,800	4	
155	F	H	Sweden	ST	9,000	23	−4 +69	80	43	650	17,600	4	Swedish version of French M50
155	Modèle 50	H	France	ST	9,000	23	−4 +69	80	43	650	18,000	4	
155	TR	H	France	ST/APU	9,700	40	−5 +66	63	43.2	830	24,000	3	
155	FH70	H	UK/ W Ger/ It	ST/APU	7,800	39	−5 +70	56	43.5	880	24,000	6	
155	M139	H	Nether-lands	ST	7,500	39	−2 +63	49	43.5	785	24,600	4	
155	FH88	H	Singa-pore	ST/APU	13,200	39	−3 +70	60	43.5		24,000	2	
155	G5	H	S Africa	ST/APU	13,500	45	−3 +75	65-82	45.5	897	30,000	3	Traverse depends upon elevation
155	KH171	H	S Korea	ST	6,890	39	−2 +68	48	43.5	826	22,000	3	Modified US M114A1
155	SB155 /39	H	Spain	ST	9,000	39	−3 +70	60	43.5		24,000	3	
155	FH77A	H	Sweden	ST/APU	11,177	38	−3 +50	60	42.4	774	22,000	3	
155	FH77B	H	Sweden	ST/APU	12,000	39	−3 +70	60	42.4	827	24,000	4	
155	M59	G	USA	ST	13,880	45	−2 +63	60	43.2	837	22,000	2	
155	M114A1	H	USA	ST	5,760	20	−2 +63	49	43.2	564	14,955	1	
155	M198	H	USA	ST	6,622	39	−5 +72	45	43.2	684	18,150	4	
155	M65	H	Yugo-slavia	ST	5,790	24	−2 +63	48	43.2	564	14,950	3	Based on US M114
180	S23	G	USSR	ST	21,400	47	−2 +50	44	88	790	29,250	1	
203	M115	H	USA	ST	14,515	25	−2 +65	60	90.7	594	16,800	0.5	

Self-Propelled Equipments

Abbreviations: C – Casemate; T – Turret; LT – Limited traverse turret; O – Open; W – wheeled

Calibre mm	Model	Type	Country	Carriage	Wt kg	Barrel Cals	Elevation °	Traverse on carriage °	Shell Wt kg	Muzzle Velocity m/sec	Max Range m	Rate of fire rpm	Remarks
105	Mle 61	H	France	C	16,500	23	−4.5 +70	20	16.2	56.8	14,000	12	AMX 13 tank chassis
105	Type 74	H	Japan	T	16,500				19		11,300	12	
105	Abbot	G	UK	T	17,463	31	−5 +70	360	16	705	17,300	12	
105	M52	H	USA	LT	24,040	22.5	−10 +65	120	15	472	11,200	3	M44 chassis
105	M108	H	USA	T	22,452	22.5	−4 +74	360	15	473	11,270	3	M109 chassis
122	Type 54	H	China	O	15,300	23	−2.5 +63	45	21.7	515	11,800	4	
122	M1974	H	USSR	T	16,000	40	−3 +70	360	21.7	690	15,300	4	
152	Type 83	H	China	T	30,000	34	−5 +65	360	43.5	655	17,230	4	
152	DANA	H	Czechoslovakia	W/O	23,000	34	−3 +60	360?	43.5	655	18,000	4	
152	M1973 (2S3)	H	USSR	T	25,000	34	−3 +65	360	43.5	655	18,500	4	
152	2S5	G	USSR	O		50					27,000		Data provisional
155	F3	H	France	O	16,700	33	0 +67	50	43.2	765	21,600	4	AMX 13 tank chassis
155	GCT	H	France	T	42,000	40	−4 +66	360	43.2	810	23,300	4	
155	L/33	H	Israel	C	42,250	33	−3 +52	60	43.7	725	21,525	4	M4 Super Sherman tank chassis
155	M50	H	Israel	C	31,000	23	0 +69		43	650	17,600	2	
155	M72	H	Israel	T		33	−3 +65	360	43.7	725	20,500	4	Various tank chassis possible
155	Palmaria	H	Italy	T	46,000	41	−4 +70	360	43.5	933	24,700	4	
155	Type 75	H	Japan	T	25,300	30	−5 +65	360	43.5		19,000	4	Also fires US M109 ammunition
155	G6	H	S Africa	W/T	36,500	45	−5 +75	80	45.5	897	30,000	3	
155	ATP	H	Spain	T	38,000	39	−5 +65	360			24,000	4	Still under development
155	Bandkanon	G	Sweden	C	51,000	50	−3 +40	30	48	865	25,000	15	Automatic loading
155	AS-90	H	UK	T	36,000	39	−5 +70	360	43.2	827	24,700	2	
155	M44	H	USA	C	28,350	20	−5 +65	60	43.2	569	14,600	1	Chassis derived from M41 light tank
155	M109	H	USA	T	23,769	20	−3 +75	360	43.2	561	14,600	1	
155	M109A2	H	USA	T	24,950	32	−3 +75	360	43.2	684	18,100	1	
175	M107	G	USA	O	28,165	60	−2 +65	60	66.6	923	32,700	0.5	
203	M110	H	USA	O	26,355	25	−2 +65	60	90.7	594	16,800	0.5	
203	M110A2	H	USA	O	28,350		−2 +65	60	92.5	711	21,300	0.5	
203	M1975	G	USSR	O	40,000	60?	0 +60	45?			30,000		Data provisional

Field Multiple Rocket Equipments

Note: Weight of rocket is weight as fired, including fuel and warhead

Calibre mm	Title	Country	Wt Rocket kg	Wt Warhead kg	Length Rocket m	Tubes	Mounting	Minimum Range m	Max Range m	Remarks
51	FIROS-6	Italy	4.8	2.2	1.05	48	Truck		6,550	
70	LAU-97	Belgium		4.3		40	Tracked		8,000	Also on Land Rover chassis
70	SBAT-70	Brazil	9	4		36	Trailer		7,500	
80	VAP	Egypt	12		1.50	12	Truck		8,000	
81	RWK-014	Switzerland		16	1.60	30	Armd Car	4,000	10,000	
105	Pampero	Argentina	30	11	1.45	16	Trailer		12,000	Can also be truck-mounted
107	Type 63	China	18.8	8.3	0.84	12	Trailer		8,500	Becomes Type 81 when truck-mounted
108	FGT-108	Brazil	17	3	0.97	16	Trailer		7,000	
110	LARS	W Germany	35	17.3	2.26	36	Truck	6,000	14,000	
117	Kung Feng VI	Taiwan	60		1.80	45	Truck		15,000	
122	Type 81	China	66.8	19.2	2.87	40	Truck		20,580	Based on Soviet BM-21
122	Type 83	China	66.8	19.2	2.87	24	Truck		20,580	
122	RM-70	Czecho-slovakia	77	19.4	3.23	40	Truck		20,380	Also smaller rocket with smaller range
122	FIROS-25	Italy	52.5	17	2.58	40	Truck	13,500	25,000	
122	BM-21	USSR	77	19	3.23	40	Truck		20,380	Also short-range rockets
126	Kung Feng IV	Taiwan	25		0.80	40	Tracked		9,000	Also Kung Feng III trailer-mounted
127	SAPBA-1	Argentina	54	18	2.23	36	Truck		20,000	
127	SBAT-127	Brazil	48	22		12	Trailer		14,000	
127	SS-30	Brazil	68		3.9	32	Truck	9,000	30,000	
127	Valkiri	S Africa	60		2.68	24	Truck	8,000	22,500	
128	M-63	Yugoslavia	23	7.5	0.81	32	Trailer	2,000	8,600	Also 8- & 16-barrel versions for export
128	M-77	Yugoslavia	65	20	2.60	32	Truck		20,000	
130	M51	Austria	24		0.8	32	Truck		8,200	Czech launcher on Austrian truck
130	M51	Czecho-slovakia	24		0.8	32	Truck		8,200	
130	Type 63	China	32.8	14.7	1.05	19	Truck		10,350	
130	Type 70	China	32.8	14.7	1.05	19	Tracked		10,350	
130	Type 82	China	32.8	14.7	1.06	30	Truck		10,200	
130	Type 75	Japan	43	15	1.86	30	Tracked		15,000	
130	Kooryong	S Korea	54	21	1.79	36	Truck	10,000	23,000	
132	BM-13-16	USSR	42.5		1.74	8	Truck		9,000	Obsolete in Soviet service
140	WP-8	Poland	40	19	1.092	8	Trailer		9,800	
140	Teruel	Spain	76	19	3.23	40	Truck	6,000	28,000	
140	BM-14-16	USSR	40	19	1.09	16	Truck		9,800	
140	BM-14-17	USSR	40	19	1.09	17	Truck		9,800	

Calibre mm	Title	Country	Wt Rocket kg	Wt Warhead kg	Length Rocket m	Tubes	Mounting	Minimum Range m	Max Range m	Remarks
140	RPU-14	USSR	40	19	1.09	16	Trailer		9,800	For airborne formations
160	LAR	Israel	110	50	3.31	25	Tracked	12,000	30,000	Also other tube configurations
180	FGT-X-20	Brazil	120	40	2.78	3	Trailer		25,000	Also tracked (tank) mounting
180	SS-40	Brazil	152		4.2	16	Truck	15,000	35,000	
210	SAKR-8	Egypt	675	200	6.50	4	Truck		80,000	Also tracked carrier
220	BM-22	USSR	360		4.80	16	Truck	5,000	40,000	
227	MLRS	USA	307	154	3.94	12	Tracked		32,000	
240	BM-24	Israel	110	48	1.29	12	Truck		10,700	Adapted captured Soviet BM-24
240	BM-24	USSR	112	47	1.18	12	Truck		10,300	
250	BM-25	USSR	455		5.82	6	Truck		56,000	Liquid propellant
284	Type 74	China	127		2.47	10	Truck	1,500	15,000	
290	MAR 290	Israel	600	320	5.45	4	Tracked		25,000	
300	FGT-X-40	Brazil	654	147	4.85	3	Tracked		68,000	
300	SS-60	Brazil	595		5.60	4	Truck	20,000	60,000	
307	Type 67	Japan	573		4.50	2	Truck		28,000	
320	WS-1	China	520	150	4.52	4	Truck	20,000	80,000	

INDEX

In series with:

Armour 2000
Peter Gudgin Spring 1990

Sea Power 2000
Bernard Ireland Spring 1990

Air Power 2000
Michael Gething Summer 1991

Of related interest

Military Small Arms of the 20th Century
Ian V Hogg (New edition in preparation)

Panzer: A Revolution in Warfare
Roger Edwards

- Which current guns will still be deployed in AD2000?
- How will they be adapted? What new projectiles will they fire?
- Which guns currently at the prototype stage will be in service?
- What will move from the drawing board into production?
- What new techniques are planned for firepower, mobility and accuracy?

THE '2000' SERIES

From early 1990 through to late 1991, Arms and Armour Press will publish a short series of volumes with the above suffix. The aim of the range is to present informed forecasting on the state of military hardware at the turn of the century – not 'sci-fi dreaming' but reasoned prediction based on the current equipment in production, items at prototype stage, equipment known to be on the drawing board and each author's consideration of what expected development will create.

The series will thus advance the understanding of his subject on the part of the lay follower of the military equipment scene and enable him more thoroughly to follow the evolving state of the industry. The reader will relish the opportunity to gain an 'inside' view of trends and developments and so gain an enhanced awareness of his topic.

Each book will be profusely illustrated with photographs and drawings.

The selected authors have been chosen for their affinity with the industry concerned, their appreciation of the manner of its change and their ability to predict trends from this background of knowledge and first-hand information.

ISBN 0-85368-983-0